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FOREWORD

In the fall of 1819 Dr. Daniel Drake returned from a meeting of the Ohio Legislature with two charters. One was the charter for the Cincinnati College, a general academy, and the second was the act establishing the Medical College of Ohio. This was a conspicuous event in the history of education in Cincinnati because the Cincinnati College is now the University of Cincinnati and the Medical College of Ohio is the School of Medicine of that university.

Daniel Drake was the foremost figure in education in Cincinnati during the early decades of the nineteenth century. Emerson said that *"an institution is the lengthened shadow of a man"*. Certainly this aphorism applies directly to Drake and the College of Medicine of the University of Cincinnati and, in a broad sense, it applies to Drake and the University as a whole.

The College of Medicine of the University of Cincinnati, now in its one hundred and thirty-seventh year, is the oldest medical school west of the Alleghenies which has remained in continuous operation. Only Transylvania was established in an earlier year and that school failed to survive the Civil War.

After bringing the Medical School and the Cincinnati College into existence, Drake's next major move was the founding in 1823 of the Cincinnati Hospital which in turn was to become the Cincinnati General Hospital. In 1870 the Cincinnati College became the University of Cincinnati and it has operated since that date as a municipal university. In 1896 the Medical College of Ohio became the Department of Medicine of the University of Cincinnati. In 1909 the Miami Medical College, which had been a flourishing and independent institution for more than a half-century, joined the University under the pressure of the Flexner study. In 1925 the final legal step was taken which consolidated the University's Medical School and the Cincinnati General Hospital as an integrated unit for teaching and medical research. For almost a century the Medical College had used the clinical facilities of the Cincinnati General Hospital as its principal teaching hospital, but the arrangement was in the nature of a rather loose affiliation. With the completion of the new Cincinnati General Hospital in 1915 this affiliation became more definitely delineated, but in 1925 the new charter of the City of Cincinnati provided that professional

care of patients, teaching and research would henceforth be a responsibility of the Board of Directors of the University of Cincinnati, that responsibility to be exercised through the University's School of Medicine.

In retrospect it is clear how the shadow of Drake falls across 138 years and justifies Osler's remark to the effect that everything good in Cincinnati was started by Daniel Drake, justifies it at least as far as education is concerned, both medical and general.

With the turn of the century, the second great figure in Cincinnati in medicine was to appear in the person of Christian R. Holmes. Many men dream dreams and see visions, but only in rare instances does a man come with the inspiration of his visions so ingrained in the very depth of his soul that the mysterious, transcending and almost superhuman sources of faith and courage are tapped, releasing that indomitable determination which converts visions into reality. Such a man causes civilization to move forward. Such a man was Christian R. Holmes. In the medical history of Cincinnati he alone stands shoulder to shoulder with Daniel Drake. Their accomplishments remain equally incomprehensible to ordinary men.

It is certain that his idea—a great modern teaching hospital into which should be integrated a university medical school—was born before 1895 because by that time he was already at work on the project. To many of his fellow citizens, including a large number of the medical profession, his ideas seemed fantastic and too utterly extravagant, but Holmes, who would not be satisfied with complacent mediocrity, believed in the wisdom of the people and took his story to them. Gradually public opinion rallied to his support, and in 1902 the first step was taken when a bond issue was passed to initiate the venture, acquire land and execute definite plans. As the magnitude of the undertaking became more apparent, the strength of the opposition grew. Most men would have compromised, but he stood resolute. His fellow citizens provided the money through a succession of bond issues and in 1914, twelve years after the first definite step had been taken, the new Cincinnati General Hospital was a dream translated into brick and mortar. A year later private philanthropy provided a half-million dollars to build the Medical School in immediate proximity to the General Hospital and, as already stated, the intimate relationship between the Hospital and the Medical School became a legal integration under the charter of the City. Before this final step, war descended upon the country and with many of his newly recruited faculty, Dean Holmes entered the service of the Nation. When he was discharged from military service in 1919, only a few months were left to him. He did not live to enjoy the fruits of his labors for he died in January of 1920.

Implicit in Holmes' idea of hospital-medical school was the development of what are now generally known as geographic full-time clinical departments. This program began when Roger Morris was brought to Cincinnati to be Professor of Internal Medicine in 1916, and the development followed in the Departments of Pediatrics and Surgery. A gift from the Carnegie Foundation, matched by private philanthropy in Cincinnati, provided the basic financial

support for the establishment of a modern university's department of surgery. In 1922 the late Dr. George J. Heuer was named Carnegie-Holmes Professor of Surgery. From Johns Hopkins Medical School, he brought with him to Cincinnati Dr. Mont R. Reid, Dr. B. Noland Carter, and Dr. Max Zinninger. The following year the late Dr. William DeWitt Andrus was added to the group. Dr. Reid came as Associate Professor of Surgery. Doctors Carter, Zinninger and Andrus were the nucleus of the new residency system which Professor Heuer established following a general pattern of the Hopkins residency.

The residency program under Dr. Heuer flourished amazingly and, as it developed, the Department of Surgery grew in strength as well as in numbers. When, after ten years, Dr. George Heuer left Cincinnati to accept the Professorship of Surgery at Cornell in the new Cornell-New York Hospital Medical Center, he took with him five men and still left the nucleus of a strong department.

Dr. Mont R. Reid succeeded to the Professorship in 1932 with Dr. Carter and Dr. Zinninger remaining as his right and left bowers and the development of the department continued with hardly a faltering step. Under the inspiration and leadership of Dr. Reid, plans for a new pavilion which would provide operating rooms and modern research laboratories for the Departments of Medicine and Surgery were developed. The second World War delayed the completion of this program and the building was not finished until after Dr. Reid's death in 1943. Most appropriately this splendid building now bears the name of the Mont R. Reid Pavilion. Its modern operating rooms and fine research facilities have made it possible for the Department of Surgery to maintain its significant place in the training of surgeons and have corrected a previous inadequacy in the field of surgical research.

Upon Dr. Reid's untimely death in 1943, the Professorship passed to Dr. B. Noland Carter and upon his retirement in 1952, Dr. William Altemeier became the Carnegie-Holmes Professor of Surgery and Head of the Department.

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RADIATION HAZARDS IN THE PRACTICE OF SURGERY

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In the past few years more attention has been directed toward the beneficial and harmful effects of radiation than in the entire period since its discovery. It is indeed by the measure of history a mere turn of the page since Roentgen discovered *"a new kind of ray"* in the physics laboratory at the University of Wurzburg. X-rays, radium and radioisotopes have served well the diagnostic and therapeutic desires of the physician, possibly better than almost any physical agent in the history of medicine. Many complicated attempts at diagnosis which ended in a trail of confusion only a few years ago now become realities with the application of a few simple maneuvers wrought by the advantages of ionizing radiations.

Ionizing radiations are produced electrically by generators and roentgen tubes, from naturally occurring radioactive elements or by artificially produced radioactive isotopes from nuclear reactors and cyclotrons. The extraction of natural radioactive material from ores has been one of the most significant contributions of the last century. Still others have been produced through the medium of nuclear reactors, which were unknown before the last decade. While the benefits of these ionizing radiations have been great, it is also true that individuals charged with the responsibility of administering these materials have, in many instances, suffered immeasurably and even unnecessarily. Proof of the injuries to many workers from these substances is well documented and only too clearly indicated the dangers and injuries which accrue as a result of prolonged use without adequate protection.[1-6] Even in the first year of Roentgen's discovery of x-ray it was observed that abnormalities, not attributable to other causes, were developing, such as temporary or permanent baldness, anemia or hematologic abnormalities.[8] Less than two years later, reports of damage to the skin were recorded, and since that time the medical literature has described numerous instances of radiation injury. It is not commonly recognized by physicians other than radiologists that their association with ionizing radiation may be harmful, and the individual utilizing sources of these rays may be exposed to a far greater degree than he recognizes.

It is this group with whom we are mainly concerned. The surgeon who unwittingly is exposed to radiation and does not recognize the hazard becomes an object of serious concern. Biologically, x-rays, gamma rays, alpha and beta particles differ for the most part only in the distribution and magnitude of the damage produced. The tolerance of maximum permissible dose from external sources of radiation is at present 300 milliroentgens (0.3 r) per week for total

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body exposure. Doses to the hands may be 1500 milliroentgens (1.5 r) per week.[5] These values apply generally at present to exposure received from the application of x-rays, radium and isotopes in medicine. There is a definite possibility that these maximum values may be decreased in the next few years.

General Surgeon: The general surgeon is often exposed to x-radiation as a result of his contact with fluoroscopic or special radiographic procedures. There are certain hazards which he must recognize if he is to utilize these technics and he must by all means be as adequately protected as the radiologist. Certain rules will minimize radiation exposure in fluoroscopy so that tolerance doses will not be exceeded.

For diagnostic x-ray equipment, they are:

1. The central ray must be focused properly in the lead glass-covered fluoroscopic screen. Not infrequently the tube is off center and when the shutters are wide open, primary radiation may strike the operator and other observers.

2. Even when the shutters are opened to their fullest extent, the borders of the shutters must be visible on the fluoroscopic screen. These shutters may also be out of alignment permitting exposure of the operator to the primary beam.

3. At least 1 millimeter of aluminum must be inserted between the tube and table top to decrease the dose of the primary beam to a reasonable limit. If 2 or 3 millimeters of aluminum are used as a filter, there will be no change in the visibility, but the dose will be decreased one-half to one-third of the value with only 1 millimeter of aluminum.

4. The milliamperage used should never exceed 5 milliamperes.

The following rules for the protection of the operator should be observed:

1. The eyes should be accommodated to darkness for approximately 5 minutes, either by wearing red goggles or remaining in a totally dark room.

2. A lead rubber apron and lead rubber gloves must always be worn when operating a fluoroscope. These protective coverings should have a minimum lead equivalent of ¼ millimeter.

3. Protective devices such as gloves and aprons should be surveyed periodically for cracks and deterioration.

4. Manipulation under the fluoroscope should be kept at a minimum. Whenever possible roentgenograms should be substituted for fluoroscopy so as to decrease exposure both to the patient and operator.

5. An increase in milliamperage should not be regarded as a substitute for proper accommodation during fluoroscopy.

Since the radiation effect is probably cumulative, the exposures thus encountered must not be considered lightly. The surgeon should ascertain that the amount of radiation emitted from the fluoroscopic tube is known to the radiologist and will not result in a hazard to him as either observer or examiner.

When these precautions are observed and the primary protective measures are utilized, radiation hazard is reduced to a minimum. Film badges and radiation meters can indicate accurately the amount of radiation in any site and it is of the utmost importance that such measures be constantly carried out in order to insure the necessary protection for all.

One of the main sources of violation of radiation safety occurs when the surgeon used the fluoroscope for manipulation and reduction of fractures. In one institution which we surveyed, the daily tolerance to both local areas and general body radiation far exceeded the allotted safety, and subsequent follow-up examination revealed changes about the fingernails of those who worked with a particular fluoroscope for several months. Such changes to the soft tissue may alter the normal architecture and can result in subsequent development of squamous cancer. It is notorious that amputation of the fingers and hands have been performed in persons who have been over-exposed from improperly controlled fluoroscopic examinations. In all instances, these exposures could have been regulated and the changes could have been avoided by the use of proper technics and equipment.[7]

Repeated surveys for safety of x-ray equipment and protective devices must be carried out to protect against deviations which have occurred as a result of prolonged usage or where new hazards have been instituted because of repair. The output of x-ray tubes in roentgens per minute should be calculated several times each year to obviate excessive dosage not readily recognized. In one installation, we found the amount of secondary radiation to be considerably higher than the accepted daily tolerance dosage, and then noted that the intensity of the primary beam at the table top was 55 r per minute. This excess radiation was due to the fact that the tube had been removed at some prior time for minor repairs and the filter had not been replaced.

Of considerable interest to the general surgeon should be the studies concerning the use of radioactive isotopes which are becoming of great importance in surgery for diagnosis, for therapy and for research. These materials may be administered either orally or parenterally to the patient or may be used as sealed sources in the same manner as radium or radon. If given orally or parenterally, they may be given in small amounts (tracer levels) for diagnosis and research or in large amounts (millicurie levels) for therapy. In order to insure maximum safety both to the patient and physician, the use of artificially produced isotopes is regulated by the Atomic Energy Commission.[4] In general, there is no hazard to the patient or physician from radioactive isotopes given as tracer substances. Rubber gloves provide adequate protection from skin contamination only.

The isotopes used clinically emit beta particles and most of them emit gamma rays. When used internally about 85–90 per cent of the radiation is given off by the beta particles; about 10–15 per cent is produced by gamma radiation as for example by I-131 and Au-198. When used as sealed sources, the beta radiation is absorbed, so that only gamma radiation is emitted. Dosage levels encountered following the administration of therapeutic levels of isotopes are often hazardous to the physician and his assistants.

An important rule is that therapeutic doses of isotopes should not be given to patients in a terminal state. If the patient will not live for at least 3 to 6 months, especially when therapy is only palliative, such treatment should be withheld. A satisfactory clinical response to radioisotopes will not be observed for a period of 2 to 8 weeks following administration of the dose. Thus exposure to ward personnel and physicians can be minimized.

The general surgeon, however, may be called upon to perform emergency surgery in a patient following the therapeutic use of radioactive gold. In performing such surgery, he should be aware of the amount of radiation he and his assistants are receiving and be given some estimate as to the amount of radioactive materials still present in the abdomen at the time of operation. In such event, the radiation therapist or physicist should be consulted so as to determine the extent of the radiation hazard.

If emergency surgery is required within 1 to 10 days following the instillation of 75-150 millicuries of Au-198 into the peritoneal spaces, it is quite probable that the hands of the surgeon would receive an exposure well above the tolerance dose. When colloidal radioactive gold is given intraperitoneally or intrapleurally, about 50 per cent is taken up by the serosal surfaces in 24–48 hours and about 75–85 per cent in 3 days. The remaining Au-198 is in the fluid. On entering the abdomen the radioactive fluid must be collected in a special container. If there are 100 millicuries of Au-198 present at the time of emergency surgery, the beta ray intensity at any point inside will be of the order of 20 rep/hr and the gamma dose will be about 4 r/hr. Double heavy rubber gloves would reduce the beta dose to 5 rep/hr, but would definitely limit the dexterity of the surgeon with the usual surgical gloves, and the tolerance dose to the hands would be received in about 2–3 minutes. In an emergency a dose of 100 r to the hands and 25 r to the whole body is permitted once in a lifetime.[5]

If doses of the order of 50 millicuries of I-131 are present in the thyroid gland, the dose rate over the gland itself may be as much as 25 r/hr. At 10 cm., the dose would be reduced to 1 r/hr and at 50 cm. to 0.04 r/hr. So high a dose would be found only occasionally in the treatment of neoplasms of the thyroid gland.

There is relatively little hazard from therapeutic doses of P32 since the amounts administered are much less than in the case of other isotopes and since P32 is distributed widely throughout the body. It emits only beta radiation.[9]

More detailed information concerning exposure to therapeutic doses of radioisotopes within the body can be obtained from Handbook 56 "Safe Handling of Cadavers Containing Radioactive Isotopes", issued by the National Bureau of Standards.

Gynecologic Surgeon: The role of the gynecologic surgeon often includes the application of radioactive sources to destroy neoplasms of the cervix and body of the uterus. These radioactive materials are prepared for him and delivered to the operating room. The dosage received by the surgeon depends upon the number of pateints treated, the amount of radium which is used, and the time of manipulation. Over-exposure may be due to protracted handling which occurs during the loading of the applicators or during the actual implantation into the body.

In reviewing the technic employed by the gynecologist, measurements have been made in the operating room during an implantation when 60 or 70 milligrams of radium have been prepared. Under such circumstances the total body dose to the surgeon is approximately 300 milliroentgens per hour. In the usual case, this amount is not excessive especially since the time of implantation is usually less than 1 hour. If the operator should be exposed to 300 milliroentgens,

he has received the tolerance dose allowable for 1 week. During the application of the radium source, the greatest amount of radiation occurred in the region of the right hand and wrist which received approximately 450 milliroentgens per hour. The fingers of the right hand have received a dose of 600 mr. per hour during the process of packing the radium in place. If the operator is cognizant of the amount of radiation received and works expeditiously, he should be in no danger as a result of exposure to radiation, either locally or to the whole body. One method of avoiding over-exposure to total body radiation is the elimination of radium from the proximity of the operator during the preparation of the patient. It is common practice in some operating rooms for the radium to be present on the operating table during the entire procedure. If there is a delay in the insertion of the application, the operator may be receiving constant exposure from the source which is in close proximity. If the radioactive sources are in shielded containers and are placed in another room until the operator has completed the dilatation, he may then signal for the radium to be brought in. In this way the surgeon will receive considerably less radiation than if he had been exposed during the entire procedure.

The use of interstitial radiation also presents hazards. Under these circumstances the operator's fingers are ordinarily more exposed than during the procedure of intrauterine or intravaginal applications. While the sources are smaller, the intensity increases as the radioactive sources are inserted into the desired site, so that the operator receives the highest doses as the final needles are placed. By proper planning of the arrangement of the needles before insertion, the operator can lessen his exposure. As a general rule, radiation received during cobalt 60 implantations approximates the dose rates received from equivalent amounts of radium.

An additional hazard may be encountered in the handling of radium tubes and needles. Although rupture of radium containers is relatively uncommon, heat sterilization may produce such an explosion precipitating a very serious threat to the operator and other personnel should there be an escape of radium. For this reason, cold sterilization is preferable to autoclaving or boiling. In the event of such an accident, one hazard which must be recognized is that the radium element may be inhaled, ingested or absorbed by the body. When such an accident has occurred, the long-lived alpha-emitting isotopes represent a particular threat. The amount of body retention depends upon the type of radium used. Radium sulphate, which is insoluble, is less readily absorbed than radium chloride or radium bromide, which are soluble.[11]

Urologic Surgeon: It has been common practice during retrograde pyelography for urologists to remain seated at the foot of the table while roentgenograms are being made. This practice is to be avoided, because it exposes the operator to scattered radiation in sizable amounts which may be serious if continued over a period of years.

In recent years, the urologic surgeon has become interested in the treatment of carcinomas of the prostate and bladder with radioactive sources.[10] The use of radioactive colloidal gold for the treatment of carcinoma of the prostate has

been reported and is stimulating new interest in this disease.[3] In carrying out the injection of gold, a lead shielded syringe is required. Since the finger of the operator is inserted in the recturm during injection, the hazard encountered is similar to that of insertion of interstitial radium. A separate team should be utilized for abdominal closure if the prostate has been injected via the suprapubic route. Urine and secretions from wounds during the first 24 hours should be stored for a period of 10–14 days before being discarded. The urologic surgeon may be faced with emergency surgery in patients who have had radioactive materials injected, and the same principles which apply for the general surgeon in treating the abdomen should likewise be followed by the urologist.

The Neurosurgeon: The neurologic surgeon is subjected to radiation from an increasing number of diagnostic x-ray procedures. During angiography the total body dose to the operator is about 20–30 milliroentgens in a well controlled procedure. In carrying out cerebral air studies or angiography, protective cones on the x-ray tube will eliminate overdosage to the hands and body of the neurosurgeon.

Radioisotopes are finding increasing usage for diagnosis in tracer levels. Hazards from these technics are minimal. Intracerebral injection of therapeutic doses of certain isotopes has been utilized and such procedures are subject to the same hazards and precautions as in other regions of the body.

Thoracic Surgeon: The use of cardiac catheterization and injection of radioactive materials poses for the thoracic surgeon sources of ionizing radiation.[2] The total body radiation during cardiac catheterization has been recorded between 15 and 40 milliroentgens per case. The knowledge of the amount of radiation received will add considerably to possibilities of protection during such procedures. The use of radioactive gold at the operating table for injection of malignant lymph nodes bearing malignant tumor may be a source of hazard for the thoracic surgeon. The thoracic surgeon may be required to remove radioactive pleural fluid in order to afford symptomatic relief to patients. The hazards encountered in these situations are the same as described previously.

CONCLUSION

The impact of radiation upon the lives of all physicians becomes increasingly important and the knowledge of protection must be fully realized not only by the radiologist but the surgeon and all individuals who are exposed to repeated sources of radiation.[12] The problem of protecting these individuals from the harmful effects has been existent since their discovery. Even the smallest amount of radiation has some effect on the living human body. Even if the harm is normally undetectable by the individual, genetic damage can result from single minute exposures. It is, therefore, of the greatest importance to prevent perceptible harm or damage and minimize the detectable damage even though we cannot eliminate it entirely.

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DIVERTICULOSIS AND DIVERTICULITIS OF THE COLON

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Although the occurrence of asymptomatic diverticula of the colon is common after the age of 40, serious complications often arise which may be dramatic in onset, perplexing to recognize, and difficult to manage. These considerations pertain to the ordinary type of diverticula which are seen most numerously in the sigmoid and descending colon, although at times they may extend throughout the colon to the cecum. They are regarded as degenerative lesions, due to out-pouching of the mucosa through defects in the muscularis alongside perforating arteries and veins. It is important to recognize that congenital diverticula of the colon also occur. These appear most frequently in the cecum or ascending colon, usually are solitary, contain all layers of the bowel in their walls, and, like the other diverticula, seldom cause symptoms unless inflammation occurs. In such instances they usually present signs and symptoms suggestive of, or indistinguishable from those of appendicitis.

Under ordinary circumstances the diagnosis of the presence of diverticula can be established with ease by the ordinary barium enema, with or without double contrast. Not infrequently, however, multiple diverticula may resemble somewhat the appearance of multiple polyps, and since the treatment of multiple polyposis is different from that of diverticulosis, it is important to recognize certain differential features. One simple method for differentiation is to give a patient with suspected multiple polyps, a teaspoonful of powdered barium once a day for 5 to 6 days. At the end of that period, a flat film of the abdomen is made. If diverticula are present, they will appear, as barium filled areas outside the bowel, while polyps will not be demonstrated (figs. 1 and 2).

If we exclude the congenital diverticula of the cecum and ascending colon, and consider only the usual degenerative, multiple diverticula of the colon the following observations may be made. If symptoms occur, they may vary widely depending upon many factors. The most severe manifestations arise as the result of acute inflammation in one or more diverticula. This may proceed to free perforation with peritonitis, localized abscess formation, dissecting fistulous tracts to other viscera or to the skin surface, or spontaneous regression. With repeated attacks of mild inflammation, fistulous tracts also may develop, but a commoner type or reaction is scarring and fibrosis of the wall, narrowing of the lumen and low grade intestinal obstruction. The latter may at times resemble malignant disease. Another reaction which occurs but rarely, is severe hemorrhage from the bowel. This usually follows a rather typical pattern which will be discussed later. Finally the mildest symptoms are those of an irritable colon, but since these may occur without the presence of diverticula, it is difficult to assess the importance of the diverticula in production of the symptoms.

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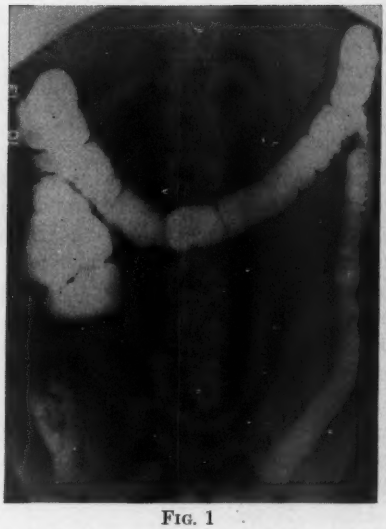

FIG. 1

FIG. 2

FIG. 1. Barium enema showing lesions which were interpreted as possibly multiple polyps

FIG. 2. Same patient as figure 1. Flat film of abdomen 5 days after daily ingestion of 1 teaspoonful of powdered barium a day, revealing multiple diverticula.

In acute inflammation with perforation, the symptoms resemble those of acute appendicitis, except that the symptoms and signs usually are in the left lower instead of the right lower quadrant. In most instances exploration through a left McBurney or low left rectus incision is indicated. If diverticulitis with free perforation can be established, the operative procedure indicated is simple drainage of the infected area supplemented by a proximal diverting colostomy. For this purpose, it is my usual custom to use the simple colostomy of the right transverse colon described by Wangensteen, although a double-barrelled or DeVine type may be used. In exceptional instances, exteriorization of the area of perforation may be accomplished, but usually it is wise not to disturb the local infected area if possible, in order to avoid opening up additional avenues for entrance of infective material into the lymphatic and vascular circulation. For this reason, simple drainage of the area, plus proximal colostomy usually is the procedure of choice. Failure to follow this simple method may, even with the use of modern antibiotic therapy, be followed by the development of infectious complications which in turn may lead to prolonged morbidity, the necessity for repeated operative procedures and even to the death of the patient. On the other hand, the use of drainage, plus proximal colostomy usually is easy to accomplish, and in general leads to a smooth convalescence, and any subsequent procedure which may be necessary can be carried out without difficulty.

If localized abscess, instead of free perforation has occurred, a different plan may be followed. Under such circumstances, and especially if the patient is seen some 18 to 24 hours after the onset of symptoms without frank signs of spreading

FIG. 3

FIG. 4

FIG. 5

FIG. 3. Patient #1. Evacuation barium enema showing diverticulitis without obstruction
FIG. 4. Patient #1. Filling barium enema on Sept. 12, 1951 showing extravasation of barium outside lumen of sigmoid.
FIG. 5. Patient #1. Filling barium enema on Jan. 4, 1952 showing rather complete resolution of diverticulitis.

peritonitis, a much more conservative attitude may be adopted. A localized abscess originating from a diverticulum usually retains its communication with the lumen of the bowel, and if the infection can be controlled, drainage of the abscess into the bowel, with spontaneous subsidence of symptoms may occur. Bed rest, continuous gastric suction, and antibiotic therapy may be indicated under such circumstances. The following case report is pertinent.

CASE REPORT

Patient #1. R. G., a white man 55 years of age, was admitted to the hospital on Sept. 5, 1951 with the following history. Some years before he had had a repair of a left inguinal hernia with recurrence. For several years he had had attacks in which the hernia protruded and became hard and tender. With these he also had chills, fever, nausea and tenderness over the hernia, with subsidence of all symptoms over a period of 24 to 36 hours. He had had such an attack beginning the previous evening. It was worse than usual and he had consulted a doctor who apparently reduced a strangulated hernia and advised hospitalization. The patient refused this advice and drove by car more than 200 miles to his home in Cincinnati. On admission, there was moderate fever (temperature 101°) and leukocytosis (23,550 per cu. mm.) but the patient did not appear ill. The hernia was obviously not strangulated at this time although there was tenderness with a little muscle spasm in the left lower quadrant. A clinical diagnosis of diverticulitis was made and the patient was treated by bed-rest, antibiotic therapy, and continuous gastric suction. Roentgenogram (fig. 3) on September 6, revealed narrowing and irritability involving the proximal third of the sigmoid with multiple diverticula and the saw-tooth arrangement, characteristic of diverticulitis. The patient responded rapidly; his temperature and leukocyte count dropped and a repeat barium enema (fig. 4) on September 12, revealed marked diminution of the extent of narrowing and irritability of the colon. However at this examination there was evidence of extravasation of barium outside the lumen of the bowel. This was interpreted as a small abscess communicating with the bowel, which represented a walled-off perforation of a diverticulum. No evidence of obstruction was demonstrated in either the filled colon, or in the film taken after evacuation of the barium. The patient was asymptomatic at this time and was discharged from the hospital two days later on September 14. He has remained well since that time. After some urging he was persuaded to return, as an outpatient for another barium enema. This was done on Jan. 4, 1952 and the following report was returned (fig. 5). "Examination of the colon with special reference to the sigmoid area shows some residual changes due to diverticulitis with inflammation described several months ago. The area of extravasation of barium beyond the lumen of the bowel is not demonstrated at this time and it appears that the lesion has healed. The evacuation film reveals many diverticula in the area and, at this time, there is not the slightest suggestion of new growth". No further treatment has seemed to be indicated.

FISTULOUS TRACT TO HOLLOW VISCUS

When fistulous tracts to other viscera have developed it is possible in certain carefully selected cases to close the fistula, and resect and anastomose the bowel in one stage. As a rule, however, this is not the safest and best procedure. If one successfully carries out such a procedure, it reduces materially the period of disability and morbidity, and with modern antibiotic therapy it can be accomplished in carefully selected cases. However, the consequences of failure in the one stage procedure are such that the long established principle of a three stage procedure still remains the method of choice in most cases. This consists of first a proximal diverting colostomy, second resection and anastomosis of the involved

bowel and closure or resection of the fistula, and third, closure of the colostomy. The following case record is illustrative of this method.

CASE REPORT

Patient #2. H. G., a 60 year old white man, was admitted to the hospital on May 23, 1955. This patient had had three episodes of right lower quadrant and suprapubic pain in 1952. Roentgenograms revealed diverticulitis of the sigmoid colon. He was treated with antibiotic drugs and had no real difficulty until February 1955, when he began passing air in his urine. For 1½ years prior to this time he had had pyuria and dysuria. Cystoscopy in February 1955 revealed a fistula entering the dome of the bladder.

I saw him first in April 1955 and on May 18 a Wangensteen type of transverse colostomy was performed. No air appeared in the urine after this procedure, the only symptom being continuation of mild dysuria. He was sent home for several weeks and then readmitted to the hospital. On May 24 resection of the diverticula-bearing area of the sigmoid was performed together with excision and closure of the fistulous opening into the bladder. Continuity of the bowel was restored by closed end to end anastomosis. The patient had a smooth postoperative convalescence. On June 4, barium given through the distal colostomy opening "showed barium to move freely down the descending, through the sigmoid colon and down into the rectum. Caliber and contour are normal and there is not the slightest obstruction. Reexamination after evacuation shows partial emptying, revealing a normal mucous membrane pattern". In June 6, the transverse colostomy was closed. The patient had a smooth postoperative convalescence. He had his first bowel movement on June 9, and was discharged from the hospital on June 16, 1955. He has remained well since.

Comment: The long duration of symptoms led to the belief that there was considerable reaction and that proximal colostomy prior to resection was safer than a one stage operation. The acute infection of the bladder subsided promptly after colostomy and this lessening of infection undoubtedly led to the benign postoperative course.

CHRONIC RECURRENT DIVERTICULITIS

Under other circumstances a different approach may be indicated as is shown by the following case record.

CASE REPORT

Patient #3. L. M., a white man 37 years of age, was first seen February 2, 1942, at which time he presented signs of a ruptured appendix with a midline mass, thought to be an appendiceal abscess. At exploration through a McBurney incision, the appendix was found to be normal, and the mass much farther medial than could be reached through this incision. A right rectus incision then was made and the mass was found to be not an abscess, but an indurated area, the size of a grapefruit, involving the sigmoid colon. A diagnosis of diverticulitis of the colon without free perforation was made. Drainage was established to the inflammatory area, powdered sulphadiazine was dusted into the peritoneal cavity and a cecostomy was done, although it was realized that this was only a partially diverting colostomy. In view of the patient's general condition and the fact that two incisions had already been made, it was decided that another incision with a complete colostomy would not be done. The patient had a rather stormy postoperative period. On the eighth postoperative day he passed a large amount of pus per rectum. Roentgenogram a few days later showed an abscess cavity in the pelvis communicating with the sigmoid colon. By this time the patient was much better clinically and within the next few weeks the drainage tract and the cecostomy both healed.

FIG. 6

FIG. 7

FIG. 6. Patient #3. Evacuation enema showing considerable area of diverticulitis without obstruction. No escape of barium into fistulas.

FIG. 7. Patient #3. Injection of radiopaque dye into fistulas of abdominal wall shows communication with sigmoid colon.

Over the next 9 years this patient was seen at irregular intervals. During this time he had had repeated flare-ups with fever, weakness, nausea and other signs of partial obstruction, always relieved by the ingestion of sulpha drugs which he took on his own initiative and on several occasions by the passage of considerable pus per rectum. During this period, two fistulas developed on the anterior abdominal wall which drained small amounts of feces and pus. On several occasions, operation to correct this situation was recommended, but the patient always refused to submit to such a procedure even though he realized that his health was below par. Finally in 1951 he agreed to surgical removal of the diseased segment of bowel. Prior to operation, it was disclosed that there was no obstruction in the sigmoid or descending colon (fig. 7). In view of the absence of obstruction or evidences of acute inflammation, a single stage resection was recommended.[2] This was carried out without incident on Jan. 9, 1951, and the patient has been well since that time.

Comment: In this particular case, the long duration of chronic infection, the absence of intestinal obstruction or evidence of active infection, led to the belief that preliminary proximal colostomy was unnecessary and that one stage resection and anastomosis was the method of choice. The use of powdered sulphadiazine intraperitoneally at the original operation may or may not have been of value. At that time it was one of the measures being used in patients with potential and established peritonitis.

OBSTRUCTION DUE TO DIVERTICULAR DISEASE

As the result of long standing chronic diverticulitis, obstruction resembling malignant disease may occur, and the differential diagnosis may be difficult. The following case report is pertinent.

CASE REPORT

Patient #4. L. C., a 55 year old physician, was admitted to the hospital on May 27, 1947 because of nausea, abdominal pain, and fever. His symptoms and signs were not too acute;

FIG. 8

FIG. 9

FIG. 10

FIG. 8. Patient #4. Filling barium enema on May 28, 1947 showing partial obstruction over long area of sigmoid with no disturbance of mucous membrane pattern. Interpreted as partial obstruction due to diverticulitis.

FIG. 9. Patient #4. Filling barium enema on July 18, 1947 showing residual diverticulitis but no significant obstruction.

FIG. 10. Patient #4. Barium enema on May 27, 1951 showing marked obstruction of sigmoid colon probably due to diverticulitis although carcinoma could not be excluded.

(temperature 100°–101°, on admission white blood cells were 17,800 per cu. mm.) and he was treated by conservative measures, consisting of nothing by mouth, intravenous feeding, and antibiotics (Penicillin and sulphadiazine). Barium enema (fig. 8) showed the presence of multiple diverticula of the sigmoid, with partial obstruction over a considerable length, but with a normal mucous membrane pattern. According to the roentgenologist there was no evidence of carcinoma. Symptoms slowly but progressively improved, and a roentgenogram on June 9 showed fairly complete relief of obstruction. He was discharged from the hospital on June 16, 1947. A barium enema obtained 2 months later (fig. 9) still showed narrowing of the luman of the bowel in the sigmoid and he was advised that resection of this segment of the colon should be carried out. He chose to have no operation at this time, and was lost sight of for several years. During this time he sustained a rather severe coronary occlusion from which he ultimately recovered. May 26, 1951 he was again admitted to the hospital. The previous evening he had suddenly developed abdominal pain, nausea, and evidence of partial circulatory collapse. On admission his pulse and blood pressure were normal. There was nausea, abdominal distension, and he had vomited several times during the preceding 12 hours. There was no fever or leukocytosis. On account of the clinical evidence of intestinal obstruction, which was confirmed by flat film and by barium enema to be present in the sigmoid, cecostomy under local anesthesia was performed on May 27. At this time the roentgenogram showed considerable obstruction which was interpreted as due to diverticular disease, although neoplasm could not be excluded (fig. 10). Six days later, June 2, resection of the sigmoid colon with end to end anastomosis was carried out. The resected specimen showed marked thickening of the wall of the bowel. According to the pathologic report, the average outer diameter of the specimen of bowel was 3 cm., the lumen 1 cm., and the thickness of the wall 1 cm. Numerous diverticula also were found with an average size of 5–7 mm., many containing fecal concretions. No neoplasm was found. This patient has remained well following resection so far as symptoms referable to the bowel are concerned although he had a cerebral hemorrhage with partial aphasia and right hemiparesis late in 1955.

CANCER AND DIVERTICULITIS

It is generally agreed that the presence of diverticula or of diverticulitis does not predispose to the development of carcinoma, but it is equally well recognized that carcinoma may be superimposed upon diverticula or diverticulosis. At times, the differential diagnosis by barium enema and by sigmoidoscopy may be difficult.[5] The pattern of obstruction due to diverticulitis generally shows a comparatively long area of partial obstruction without the shelf-like edge or mucosal distortion seen in cancer, so that the roentgenologist and surgeon usually can recognize the difference. At other times it may be exceedingly difficult to make a differential diagnosis. In most cases sigmoidoscopy is of no help. The examination at the time often is unsatisfactory, the mucosa of the bowel appearing normal as far as the sigmoidoscope can be passed. However, this usually is for a limited distance only. The instrument is straight and rigid and can be passed only through that part of the bowel that can be straightened out. As a result of inflammation, fibrosis, or adhesions outside the intestine, the bowel cannot be manipulated into a straight tube, and it finally becomes impossible to pass the instrument beyond a curve or kink without undue pain to the patient or danger of trauma or even of perforation. This is true whether the condition is due to inflammation alone or to inflammation plus neoplasm. Two patients seen recently illustrate some of the difficulties in differential diagnosis between neoplasm and diverticulitis.

CASE REPORT

Patient #5. E. B., a 66 year old white woman, was first seen on Nov. 9, 1954 because of severe lower abdominal and pelvic pain, and loss of appetite. The history disclosed that about 6 months earlier she had been treated by a proctologist for blood in the stools and constipation. At that time, in his office, he had removed a polyp high up in the rectosigmoid and had told her it was a benign polyp of the rectum. She had returned to him for a follow-up examination. He had told her that this had disclosed no evidence of return of the lesion, but she had experienced considerable pain during the examination and several hours later had a chill, followed by fever and low abdominal pain. On admission to the hospital she had a temperature of 101.5°, and white blood cell count of 26,100 per cu. mm. She complained of abdominal pain and nausea, but there was no vomiting. Abdominal examination showed tenderness, while pelvic examination revealed tenderness plus a *"frozen pelvis"*. There was no evidence of free peritonitis, and a film of the abdomen was within normal limits. It was my impression that the patient had diverticulitis and she was therefore treated with gastric suction, intravenous fluids, and antibiotics. During the next few days there was general improvement in signs and symptoms with a drop in the white blood cell count. However, symptoms then returned, the fever rose irregularly and the white blood cell count went up to 30,500 per cu. mm. Several barium enemas during this time revealed a few diverticula of the colon with an area of narrowing which could have been due either to diverticulitis or to malignant disease, although according to the roentgenologist carcinoma seemed the more likely diagnosis. Due to her failure to respond to conservative management a diverting colostomy was performed on November 22. The fever and pain disappeared promptly after colostomy and 1 month later on Dec. 17, 1954, through a lower abdominal incision, a resection of the sigmoid colon, uterus, ovaries and tubes was carried out. All of the tissues were matted together, but after a difficult dissection it was possible to find an annular carcinoma of the sigmoid which had apparently perforated and become adherent to the uterus with a small abscess between these two viscera. After resection of the colon an end to end anastomosis was done. The resected specimen showed an annular carcinoma of the sigmoid invading the posterior surface of the uterus, plus diverticula of the colon, and marked focal subacute and acute cellulitis in all the resected tissues. The patient did well after operation and the colostomy was closed on Jan. 4, 1955. Following this procedure the patient left the hospital, but returned in several months because of increasing abdominal pain, weakness, and loss of appetite. She showed increasing evidence of intestinal obstruction and after failure to respond to conservative management, the abdomen was re-explored on May 26, 1955. At this time multiple metastatic implants were found throughout the abdomen on small bowel, large bowel and all peritoneal surfaces, with large carcinomatous masses in the pelvis, surrounding and partly occluding the colon in the region of the anastomosis. Since there were multiple areas of impending obstruction of the small bowel, colostomy was not done and the abdomen was closed. The patient died about 6 weeks later.

Comment: This patient represents a case of subacute perforation of a carcinoma of the colon with partial obstruction simulating clinically a subacute perforation of a diverticulum. The unsatisfactory outcome was no doubt due to dissemination of cancer cells at the time of perforation, although at operation the appearance was that of extensive inflammatory disease, and the pathologic study of the tissue removed at that time showed only imflammation except in the immediate vicinity of the primary neoplasm.

Another patient who had somewhat similar symptoms and gross pathologic findings turned out quite differently.

CASE REPORT

Patient #10. L. B., a 55 year old white woman, was seen first in March 1955 because of lower abdominal and pelvic pain and increasing constipation. She had had three previous admissions to the hospital for similar symptoms in December 1948, November 1952 and January 1955. On each of these occasions the symptoms and signs had subsided after a short period of hospitalization. A number of barium enema studies had been made. Each of these had revealed the presence of diverticula together with narrowing of the sigmoid. On two of the studies, annular constriction was reported, and the roentgenologist had apparently been in doubt about whether this was due to neoplasm or inflammation. However after several examinations, due to the variable picture and the spontaneous improvement, he had finally reported that diverticulitis was the more likely diagnosis. After preoperative preparation with antibiotics and repeated catharsis and enemas she was admitted to the hospital on March 3, 1955 and the abdomen explored 2 days later. A mass of inflammatory tissue involving the sigmoid colon, uterus, left tube and ovary, and multiple loops of small bowel was found, the exact nature of which was obscure, but the degree of obstruction of the large bowel was much greater than had been appreciated clinically, indeed so great that resection was deemed too hazardous at this time. Accordingly a diverting colostomy of the transverse colon was performed.

The patient was sent home, but came back to the hospital a few weeks later and was reexplored on April 5. This comparatively short period was allowed because it was impossible to be sure that malignancy was not present. Fortunately considerable resolution of the inflammatory reaction had occurred in this time. The uterus and adnexa were now free from the colon, and the adhesions to the small bowel were easily freed. Resection of the sigmoid colon was accomplished, although only after a very tedious dissection, followed by end to end anastomosis. Pathologic study of the resected tissue showed multiple diverticula with regional organizing chronic, subacute, and focal acute cellulitis and no evidence of neoplasm. The patient progressed normally postoperatively, her colostomy was closed on May 26, 1955 and she has remained well since.

Comment: This patient presented a problem in diagnosis, both roentgenologically and grossly at operation, for it was never clear whether the condition was due to neoplasm, to inflammation, or to a combination of inflammation and neoplasm. Only the pathologic study and the continued well-being of the patient shows that this was subacute and chronic diverticulitis without neoplasm.

BLEEDING FROM DIVERTICULA

The relation between bleeding from the colon and the presence of diverticula has not been generally recognized, and is not accepted by many physicians although recently a number of papers describing this complication have appeared.[1, 3, 4] A number of statistical analyses of bleeding in association with diverticula have seemed to show that when bleeding occurs under such circumstances, it is due in the majority of cases to associated cancer of the bowel. While it must be recognized that in every case of bleeding from the colon, the most important duty of the physician or surgeon is to rule out the possibility that the bleeding is coming from cancer, it must also be recognized that bleeding can apparently come from diverticular disease alone, even in the absence of significant infection. Over a period of 15 years, this observer has seen at least 10 patients with massive bleeding from the colon which apparently was due to bleeding from diverticula or from a diverticulum without clinical or roentgeno-

logic evidence of infection or inflammation, or any other disease. As a result of this experience it is my opinion that diverticula have to be regarded as a possible source of severe colonic hemorrhage. The symptomology in all cases has been essentially the same. Most of the patients have been men, 60 years of age or older, who have had sudden onset of massive rectal bleeding without any other symptom, i.e. no pain, nausea, constipation, or change in bowel habit. Most of them have had moderate hypertension. In all, careful study with sigmoidoscopy plus one or more barium enemas has failed to reveal any abnormality except the presence of diverticula. Several of these patients have had two or more episodes of bleeding separated by intervals of one or more years. None has developed evidence of carcinoma over a period of years, although several are too recent for this to be significant. The first patient with this syndrome that I observed was seen in 1940 at which time he was 60 years of age. He was admitted to the hospital in mild shock following the sudden passage of bright red blood per rectum. Sigmoidoscopic examination revealed only blood coming from a higher level than could be reached through the scope. Transfusions and bed-rest led to rapid subsidence of the bleeding followed by relief of the shock. Subsequent roentgenologic studies revealed only diverticula of the colon. He is still living and well at the age of 76, having had no further bleeding and no symptoms referable to the colon.

One patient, a man 63 years of age, seen at the Cincinnati General Hospital had had 3 separate episodes of bleeding. He was admitted in his third episode. Sigmoidoscopic examination was negative, and roentgenologic examination revealed only multiple diverticula throughout the entire colon. After recovery from the acute bleeding he was treated by subtotal colectomy with ileal implantation into the rectum. Study of the resected specimen showed multiple diverticula with no other recognizable lesion.

The patient seen most recently, who seems to fall into this category, is as follows.

CASE REPORT

Patient #11. J. O., a white man aged 66, was seen at his doctor's office on Feb. 7, 1956 with a story of sudden onset of diarrhea at about 3 p.m. Stools were loose and bloody. He had a movement at the doctor's office consisting chiefly of bright red blood and a little mucous. At that time his color was good, there was no pain or nausea, the blood pressure was 160/110 (his usual pressure). Abdominal examination was essentially negative, and rectal examination negative. He was sent home while arrangements were to be made for further study. On arrival home 1 hour later, he had two very large bowel movements consisting mostly of blood. With these he vomited profusely and fainted for a short period. When his doctor arrived at about 6 p.m. the patient was very pale, covered with cold sweat, and his blood pressure was 120/70. He was admitted to the hospital shortly thereafter. Later that evening he was out of shock although still pale, with blood pressure of 136/82. Abdominal examination was negative and the patient had no complaints except weakness. Two units of whole blood were given and his blood pressure slowly returned to normal. On admission he had a hemoglobin of 12 Gm., but the next day this had dropped to 11.4 Gm. and red blood cell count was 3,790,000 per cu. mm.

Bleeding ceased as rapidly as it had started. February 11 he was given a cleansing enema which returned stool and old dark blood. Sigmoidoscopy that morning revealed no abnor-

mality. Later that day he had a barium enema which revealed numerous large diverticula with no evidence of diverticulitis, obstruction or neoplasm. Upper gastrointestinal study, together with a repeat barium enema and double contrast with air two days later, revealed nothing abnormal except multiple diverticula. He was discharged from the hospital on Feb. 14, 1956.

Comment: While it is too recent to say with assurance that this patient does not have a more serious lesion, the evidence at present points to the diverticula as the source of his bleeding.

During the same 15 year period many other patients have been seen with a similar type of bleeding in whom polyps, polypoid carcinoma, or other lesions have been demonstrated, either with or without accompanying diverticula. These have been suitably treated by resection or local excision. It is not my purpose to suggest that hemorrhage from the bowel, unaccompanied by other symptoms, is certainly due to diverticula. What I should like to insist upon is that in patients with this type of bleeding, if after careful endoscopic and roentgenologic study no cause can be found for the bleeding, and diverticula are demonstrated, these may be accepted as the source of the hemorrhage. Under such circumstances, watchful waiting for further bleeding or other signs is indicated, and more active therapy, such as exploratory laparotomy should be resorted to only if further symptoms or signs occur.

SUMMARY

In conclusion and summary, it may be stated that diverticular disease of the colon may present itself in various ways, by bleeding, intestinal obstruction, acute inflammatory episodes, or in the appearance of various types of fistulous communications. It is my belief that physicians and surgeons have been too hesitant in performing resections in patients with diverticulitis. In the past the resection of areas of diverticulosis and diverticulitis has been relatively hazardous. With modern methods and with appropriate antibiotic therapy the danger had been reduced to such an extent that patients with chronic low grade obstruction and low grade or recurrent inflammation should not be denied the benefits that can be obtained by surgical excision of the involved segment of bowel. It must be recognized by the surgeon that operative removal often is more difficult under such circumstances than in cases of neoplasm. The mesentery of the bowel frequently is thickened, shortened and fibrotic, and the ureter often is drawn up into it, so that accurate and careful dissection is essential, with early and satisfactory demonstration of the ureter before any resection of mesentery is carried out. If acute or subacute infection or significant obstruction is present, preliminary diverting colostomy should be established before resection is attempted. In cases of acute perforation, local drainage plus proximal colostomy should be done, to be followed later by whatever measures seem to be appropriate for the individual case. The simultaneous presence of diverticula or of diverticulitis and neoplasm is reasonably common, and while differentiation often is easy, at times it may be exceedingly difficult. The difficulty occurs as a rule only in those cases in which inflammation and at least some degree of ob-

struction is present. This situation usually requires a preliminary diverting colostomy, before resection can be carried out safely. It is important in such a situation, to shorten considerably the time between the colostomy and resection,[5] beyond that considered desirable in the past for inflammatory disease alone. With modern methods of surgery this usually can be achieved satisfactorily in 4–6 weeks instead of the 3–4 months formerly advocated.

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TREATMENT OF LARGE NERVES AT THE TIME OF AMPUTATION OF AN EXTREMITY: A PROBABLE CAUSE FOR PERSISTENT PAIN*

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In spite of the masses of data which have accumulated from the study of painful amputation stumps of soldiers who had lost one or more extremities from wounds of violence in two World Wars, there has been relatively little importance attached to the technical methods of handling the larged mixed nerves at the time of amputation of the part. During World War II. White[20] studied the problem of *well established* and *persistent* pain after amputation of an extremity and he emphasized the fact that no single method of *treatment* of such pain was uniformly successful. He also emphasized the fact that experience had shown that an *ineffectual* or *mutilating* surgical procedure, which might be performed in the hope of relieving *"phantom limb pain"* or *"causalgia"*, often just added more psychic trauma with further suffering and loss of morale by the patient.

Most adult amputees have the sensation that the extremity is still present. This phantom limb sensation may be present only for a brief period of time or it may last for many months, although usually it is not painful. Phantom limb sensations of this variety often disappear as soon as the patient begins to wear an artificial extremity.

In some patients, however, these sensations may take the form of severe burning or boring pain and the victims may even complain that the distal parts of the extremity are being constricted or compressed. They also may complain that a specific pain, which was present in the fingers or toes before amputation of the limb, persists unchanged in the *"phantom limb"*. Because of the great variation in the intensity of phantom limb sensations and the location or character of the pain, these patients frequently are thought to be suffering from some form of psychoneurosis.

In favor of a central origin of these sensations, particularly that the symptoms might represent an obsession neurosis, are the observations that no peripheral end-organs can account for the sensory impressions of posture, touch, and movement. The patient usually feels most vividly the parts of the limb which have the greatest representation in the cerebral cortex, especially the hand, index finger, toes and foot. Most patients report the phantom limb to be frozen in one position, a position which corresponds to that position in which the injured limb was last seen by the patient. Nervousness and emotional instability, which may be evident by the time the patient comes under observation in his quest for

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relief of pain, are thought to indicate a temperament which favors the development of an obsession neurosis.

From a clinical standpoint, no one could object to any of these observations, but when they are used to *exclude* the possibility that peripheral irritation can be playing a part in the causation of the phantom limb pain and to prove the pure psychic origin of this condition, we must agree with Livingston[13] that the evidence is inconclusive. Our own observations[8] support Livingston's contention that peripheral irritation of a larged mixed nerve, while by no means constituting the whole story, *does* represent an important etiologic factor in the syndrome of phantom limb pain.

It usually is emphasized by students of this problem that if the syndrome came as a result of peripheral irritation, the excision of the neuroma or a higher amputation of the part should cause the symptoms to disappear. Surgeons now agree that amputation at a higher level usually fails to give lasting relief. Most neurophysiologists and neurosurgeons agree that these abnormal sensory reflexes from the periphery to the higher centers of the central nervous system tend to become fixed or irreversible within a short time after extensive trauma to any large mixed peripheral nerve, and that the subsequent removal of the original site of irritation does not always completely abolish the abnormal sensory reflexes. The original idea of Mitchell, Morehouse and Keen,[14] that an ascending neuritis was responsible for the pain, has never been proved by microscopic studies of the large nerves which were excised in an effort to relieve persistent or phantom limb pain.

PREVENTION OF PHANTOM LIMB PAIN

Stimulation of the afferent pathways of large nerve trunks which have been divided certainly provokes abnormal sensory reflexes in the spinal cord and Riddoch[16] believes that the processes of healing of the proximal end of the divided nerves evoke sensations which are projected and interpreted as if the limb were still present. He states that "during the stabilizing process of healing of the divided nerves, the sensory impulses diminish, and the sensations become correspondingly fainter with the result that the phantom limb is increasingly less obvious in outline and projection; consequently it gradually approaches the stump into which it finally disappears and fades away. If, however, the phantom limb is painful, which usually is the result of grossly abnormal conditions in the stump, the phantom may persist indefinitely and retain its original position."

We are of the opinion that the most probable primary cause of the phantom limb sensations or pain is irritation of centrally conducting axones within a neuroma or at the proximal end of a freshly cut mixed nerve. These axones formerly brought impulses to the higher centers from the parts which have been removed. It is not necessary for such irritation to persist, since these abnormal sensory reflexes within the spinal cord, which the original injury provoked, cause the phantom limb sensations or pain to continue even after all known afferent somatic and autonomic pathways from the affected extremity have been severed.

The fact that surgeons throughout the world now employ more than a dozen different methods of handling the proximal stump of severed large nerves at the time of amputation of an extremity indicates to us that insufficient thought has been given to this technical step in the operation as a possible cause for reducing the incidence of persistent pain in an amputation stump. A review of our experiences at the Cincinnati General Hospital suggests that no single method has been uniformly successful in preventing persistent pain in the amputation stump or in the phantom limb. In 1945 Herrmann and Gibbs[8] reported that the incidence of persistent pain in an amputation stump was reduced to about 6 per cent when the proximal end of the severed nerve was treated by the application of a non-absorbable suture at the time of the amputation of the limb.

CRITICAL REVIEW OF METHODS

One of the oldest methods of caring for the proximal end of severed large mixed nerves in an amputation stump, and one which unfortunately is still commonly used in this country, consists of pulling the nerve as far as it will conveniently stretch, severing it with a sharp scalpel, and allowing the proximal end to retract into the areolar tissue well above the end of the amputation stump. Our studies of this method showed that 100 per cent of such nerves developed large neuromas at the cut end, and fibrous tissue grew into the nerve and into surrounding tissue and caused complete fixation of the nerve in the stump. All these patients developed painful areas in the amputation stump.

In 1908 Bardenheuer[1] modified this method by turning the cut end of the nerve back and implanting it beneath the sheath of the same nerve at a higher level; thus forming a loop. This method does not prevent the formation of excessive scar tissue or neuroma formation. The amputation stump usually remains painful.

In 1916 Krüger[11] suggested that the large mixed nerves be crushed by a heavy hemostatic forceps. We found that this method disrupts the perineurium of the large nerves and results in the formation of multiple neuromas on the proximal end of the severed nerves.

Sicard[18] was the first (1916) to suggest the use of chemical substances to destroy the axones in the mixed nerves. He demonstrated that 60 per cent ethyl alcohol, when injected into the proximal end of the cut nerve, caused the degeneration of the afferent fibers only; consequently, he recommended its clinical use. We repeated his experiments and found that alcohol did cause degeneration of afferent axones but the excessive proliferation of scar tissue at the site of injection frequently gave rise to painful lumps in the amputation stump.

In 1917 Chapple[4] suggested that an epineurial cuff several millimeters in width be turned back, the neuraxes then cut off, and the cuff of epineurium pulled down and closed over the end of the nerve by means of a ligature. Our experience with this method demonstrated that, several months after the operation, there was evidence in most of our experimental animals of neuroma formation at the end of the severed nerve.

Moszkowicz[15] suggested (1918) that the proximal end of the nerve should be implanted into adjacent muscle. This method does not prevent the outgrowth of neuraxes and the formation of neuromas at the proximal end of the nerves.

In 1918 Corner[5] suggested the excision of an inverted wedge to form a *"swinging door flap"*. The edges were then sutured together. This method, like the one suggested by Chapple, did not prevent the formation of neuromas which grew out between the sutures.

The first use of the actual cautery in recent surgical history followed the recommendation of Hedri[7] in 1920. He suggested the use of a red hot cautery to seal the proximal end of a cut nerve and to *"prevent the irritating effect of secretions from the wound"*. Our experimental studies showed that severe reaction occurred in mixed nerves which had been cauterized by heat, and extensive fibrosis and neuroma formation were noted in all our experimental animals.

In 1920 Huber and Lewis[10] revived the method of Sicard but, in addition, they suggested the application of a tight ligature to the nerve. They recommended the injection of 1 cc. of absolute alcohol into the nerve at a site proximal to the ligature. This method has been widely used during the recent wars, but all our experimental and clinical studies indicate that in the majority of cases the resulting fibrosis about the proximal end of the nerve gives persistent pain and tenderness in the amputation stump.

Stookey[19] in 1922 recommended a combination of Corner's *"swinging door flap"* and the injection of absolute alcohol. We found this method to have many disadvantages, and excessive fibrosis and neuroma formation were as common as they were in those animals in which the methods were used separately.

In 1925 Laewen[12] suggested the application of intense cold to freeze the nerve. In a series of experiments we used various methods of freezing the proximal end of the nerve, including dry ice and liquid nitrogen. Subsequent histologic studies showed excessive fibrosis and rupture of the epineurium with neuroma formation in all the nerves which we studied.

Foerster[6] in 1927 suggested the injection of a 5 per cent solution of formaldehyde into the proximal end of the severed mixed nerve. This method is worthy of careful study, since all our experiments using this method showed primary degeneration of the axone cylinders without evidence of inflammatory reaction in the nerve or neuroma formation at the site of the injection. This method, with the addition of a ligature distal to the site of injection of the 5 per cent formaldehyde solution, gave no evidence of painful areas in the amputation stumps. Clinical application of this method is now in progress.

Beswerschenko[2] in 1929 again recommended Federoff's method of phenolization at the end of the nerve and the injection of liquid phenol into the proximal end of the cut nerve. Our experiments showed this method to be followed invariably by marked fibrosis, disruption of the nerve, and neuroma formation.

In 1931 Lexer suggested the electrocoagulation of the proximal end of a cut nerve. This method gave results not unlike those after use of the actual cautery and our studies indicate that the method is without merit and it should not be employed.

In 1943 Boldrey[3] revived interest in this subject and presented his own method of preventing the formation of large neuromas on the severed major nerve trunks by inserting the proximal end of the cut nerve into the adjacent bone. He made no comment as to the relative success of his own method, or the various other

methods which he reviewed, in the prevention of persistent pain in the amputation stump or in the phantom limb.

Our original studies[8] centered around what we considered the simplest and the most physiologic method of preventing regeneration of axones from the cut end of a large nerve by placing a nonabsorbable ligature tightly around the uninjured nerve trunk about 1 inch above the site of amputation. Such a ligature will always control the bleeding from the nutrient artery of the large nerve and it causes a narrow line of pressure necrosis of the nerve tissues immediately beneath the ligature (fig. 1). The regeneration of axones is prevented by the occlusion of the neurilemma sheaths: first, by the ligature itself and, later, by the ingrowth of fibrous tissue. Histologic studies made upon large nerves treated in this manner show a gradual replacement of the area of pressure necrosis by fibrous tissue until finally, after about 1 month, the epineurium completely encases the end of the nerve except for a small area of dense fibrous tissue at the extreme end.

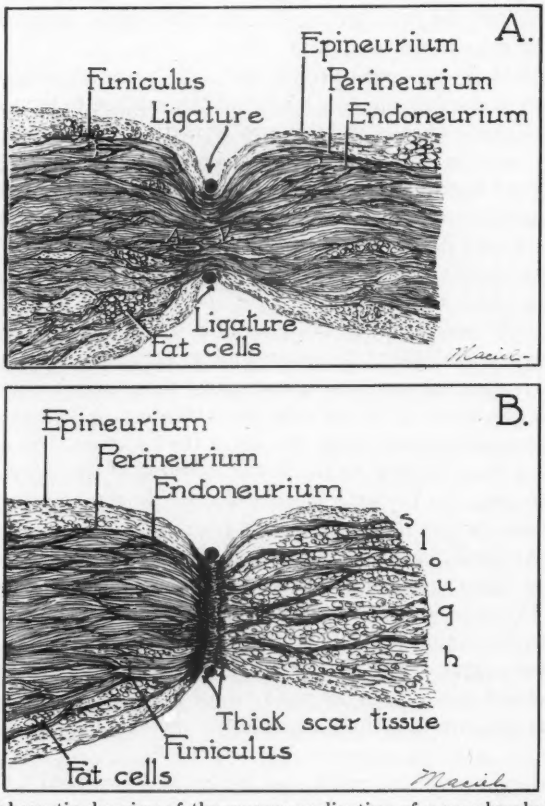

FIG. 1. A. Schematic drawing of the proper application of a nonabsorbable ligature to the cut end of a large mixed nerve. B. Note the area of ischemic necrosis surrounded by scar tissue near the end of the nerve. This prevents the outgrowth of neuraxones.

In reviewing the results of studies in our laboratories on the healing of large nerves after various methods of treatment by Schnug (1945) and Bollack (1955), and on our own clinical services, we are of the opinion that there is a distinct relationship between the treatment of the large mixed nerves of an extremity at the time of amputation and the type, intensity, and severity of the persistent pain in the amputation stump and in the phantom limb.

Schnug[17] showed that if a large nerve was crushed before the nonabsorbable ligature was applied, the neurilemma sheaths were invariably ruptured and neuromas developed in spite of the ligature. This also might happen if the nonabsorbable ligature is tied down too quickly or too vigorously and thus ruptures the neurilemma sheaths.

Ligatures therefore must be applied gently and just tightly enough to control the bleeding from the nutrient artery within the nerve and to cause an area of mild pressure necrosis to take place beneath the ligature. Ligatures of absorbable material were found to loosen or disintegrate before complete healing of the end of the nerve had taken place, and it was our conclusion that such material should not be used to ligate large nerves at the time of amputation of the limb.

FIG. 2. Photomicrograph showing terminal portion of the proximal end of a cut mixed nerve 48 days after amputation of the leg. The nerve was infiltrated with 1 cc. of 5 per cent formaldehyde solution and then a nonabsorbable ligature was applied distal to the site of injection. Only slight thickening of the epineurium was present with no evidence of neuroma formation.

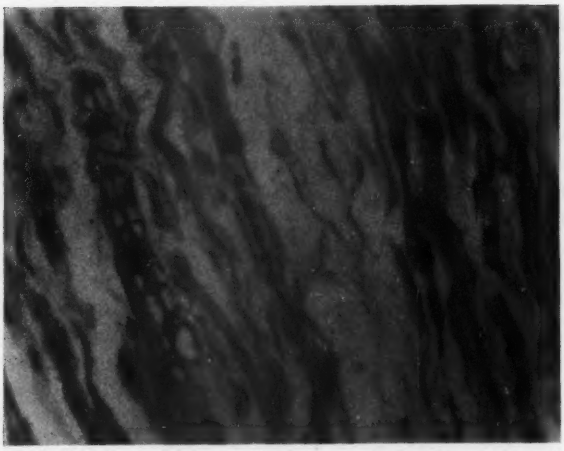

FIG. 3. High magnification of nerve in figure 2, showing various stages of reconstitution of nerve fiber 48 days after infiltration of 5 per cent formaldehyde solution. An occasional nerve fiber has a complete axone cylinder with myelin sheath, while others show various degrees of simple degeneration.

FIG. 4. Photomicrograph showing the appearance of nerve 120 days after being severed and allowed to retract. Note the flaring of the end of nerve with brush-like dispersion of the fibrils and neuroma formation.

Herrmann and Bollack[9] gave us further information by their recent studies upon experimental animals. The injection of chemical substances into the nerve trunks, to cause primary degeneration of the neurones, is being investigated further by laboratory and clinical studies. The injection of 1 cc. of 2 per cent aqueous solution of gentian violet, or 5 per cent aqueous solution of formaldehyde (fig. 2), into the proximal end of the cut nerve and then the application of a nonabsorbable ligature to allow the perineurium eventually to cover the cut end of the nerve has been studied carefully in our laboratory. Histologic studies of the proximal ends of nerves treated in this way show very little evidence of inflammatory reaction in the nerves and no neuromas or excessive fibrosis (fig. 3).

When a large mixed nerve is severed and allowed to retract at the time of amputation, a neuroma invariably forms at the proximal end of the cut nerve (fig. 4). This neuroma is always tender to touch and usually gives rise to various degrees of persistent pain in the amputation stump.

CONCLUSIONS

Our study indicates that the management of large mixed nerves at the time of amputation of an extremity is of real importance in reducing the incidence and severity of persistent pain in the stump.

Irritation of centrally conducting axones by local inflammation, excess scar formation, or the uninhibited proliferation of neuraxones forming neuromas at the end of the nerve may give rise to persistent pain in the stump, or in the phantom limb, for many months or years after the amputation of the part.

The application of a nonabsorbable ligature about the uninjured large nerve trunk at a point about 1 inch above the end of the amputation constitutes a simple and physiologic means of sealing off the end of the nerve and preventing the formation of a neuroma. The ligature, however, must be tied down gently, to prevent rupture of the epineurium.

Our most recent studies indicate that further reduction of the incidence of persistent or phantom limb pain after amputation of an extremity can be accomplished by the careful injection of 1 cc. of 5 per cent formaldehyde solution into the proximal end of the mixed nerve immediately before the application of the nonabsorbable ligature.

Further application of this method is in progress in our study of persistent pain in the stump or phantom limb pain after amputation of an extremity in man.

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EXPERIENCE WITH THE EXTENDED POSTOPERATIVE CARE OF CONGENITAL MEGACOLON*

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The sphincter-preserving "pull-through" operation for congenital megacolon is satisfactory and effective, provided immediate postoperative complications, such as leakage and fecal fistula or pelvic peritonitis are avoided. Nevertheless, even when the operation is technically successful, and the patient recovers from it uneventfully, an occasional case is seen which presents a troublesome problem in long-term follow-up care. The problem cases in this latter group are not the result of technical fault or failure, but derive from oversight with respect to the fundamental physiology of megacolon. The purpose of this report is to consider the common late complications in two categories, namely, those which result from technical accidents and errors, and those which occur following uneventful recovery from the operation.

SALVAGE OF PATIENTS IN WHOM COMPLICATIONS RESULT FROM TECHNICAL FAILURE OR ACCIDENT

In my early experience with the Swenson operation,[8] and later with the Hiatt modification of it,[3] the first 6 patients had uneventful immediate postoperative courses and, with one exception (to be considered in the second section of this report) have remained continuously well, all of them for more than 5 years. There followed an irregular series, intermingled with uneventful and permanent recoveries, in which untoward complications occurred, ranging from catastrophic to merely moderately troublesome proportions.

This experience led to a modification of operative technic, since the adoption of which I have encountered no further technical failures. The modified procedure was described in detail in a previous communication[6] and a complete recapitulation will not be offered here. However, a brief summary of it is included because this will help to clarify some of the complications which result from technical failure.

The essential feature of the Swenson operation is that sphincter function is preserved after combined abdomino-perineal resection of the achalasic (aganglionic) rectosigmoidal segment, in congenital megacolon. This is done by pulling the remaining proximal segment through the everted distal segment in an induced rectal prolapse. The result is that, in constructing the anastomosis, the sutures are placed in a reverse order from that employed in conventional intra-abdominal anastomoses. The seromuscular layer (serosa of proximal segment to muscularis of distal segment) is placed first, and the mucosal layer of sutures is placed afterwards. If silk sutures are used in the seromuscular row, and if Lembert's

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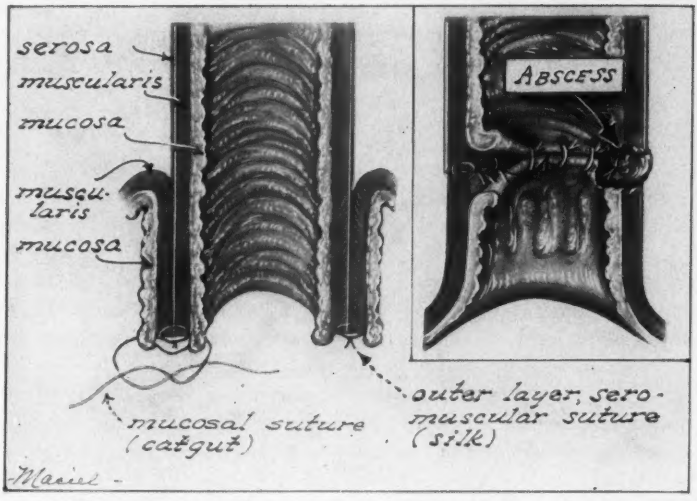

FIG. 1. Drawing to illustrate the common mechanism of leaks in the anastomosis when silk sutures of the Lembert type are used in the "pull-through" operation for congenital megacolon. This mechanism is described in the text, and can be overcome by employing inversion sutures of catgut in the seromuscular layer as well as in the mucosal layer. The complete technic of the operation, as modified from Swenson and from Hiatt, has been described in a previous publication,[6] and is not included in the present report.

stitch is employed, the knot and cut ends will extend *toward* the lumen of the bowel. No matter how carefully the mucosal sutures are inserted, there is a strong possibility, when the bowel is replaced in its normal position after the anastomosis has been completed, that one or more cut ends of the silk seromuscular sutures may protrude into the lumen of the bowel. This is schematically illustrated in the accompanying diagram (fig. 1). It is seen that the cut end of the silk suture, with its capillary action, can act as a wick to draw contaminating stool into the deep layer. The result is likely to be a localized abscess around the silk as a foreign body, and the stage is set for a serious leak in the suture line.

The danger of such an accident can substantially be reduced if catgut (usually 00 or 000) is used in both layers and if the seromuscular row is inserted as inversion sutures, turning the knot and cut ends *away* from the lumen of the bowel, and from the overlying mucosal sutures.

The following case reports (Cases 1 to 4, inclusive) illustrate the results of technical failure such as the foregoing procedure is designed to avoid. They are recorded as the basis for consideration of the management of such complications, when they do occur.

CASE REPORTS

Case 1. W. C. This 25 year old white man presented the unusual situation of having survived with true congenital megacolon from birth. Until the age of 9, he was given one to three enemas per day. He then received transitory improvement following a therapeutic spinal anesthetic, but his symptoms soon recurred and he dropped out of school in the ninth

grade because of recurrent cramps, abdominal distention, and obstipation. He learned to employ self-administered enemas and got along fairly well by taking a day off once a week to give himself a *"thorough cleaning out"*. A few months prior to admission he obtained a job which prevented his taking time off for self-treatment, and on Nov. 7, 1950 he was admitted to the hospital with a ruptured sigmoid colon. At operation the typical configuration of congenital megacolon was observed, the perforation was exteriorized, and a cecostomy was done. He recovered from his severe peritonitis, and on Jan. 4, 1951 resection and "pull-through" anastomosis was done, using Swenson's technic, with interrupted silk sutures in the seromuscular layers. Histologic examination of the resected specimen showed absent parasympathetic ganglia in the achalasic terminal segment.

The postoperative course was uneventful, and the patient began having spontaneous stools, with good control. On January 30, 26 days after operation, sigmoidoscopic examination was done, prior to surgical closure of the cecostomy. A fragment of necrotic, sloughing tissue, containing several silk sutures, came away through the sigmoidoscope, but the anastomosis appeared solidly healed and patent. It was assumed that a portion of the turned-in cuff at the suture line had sloughed away after sufficient healing had occurred in the perirectal space to prevent a leak.

Monthly follow-up examinations thereafter indicated normal bowel habits with satisfactory control, and a steady gain in weight. The patient was very happy with his result. By the end of the third month after discharge (4 months after operation) he began to note recurring constipation, and rectal examination showed a stricture at the site of the anastomosis. This was the first instance of this complication that we had encountered and it was viewed with much more concern than would now be the case. After a few weekly dilatations it was concluded that the stricture was unmanageable, the original operation was pronounced a failure, and on June 1, 1951 an abdomino-perineal resection with permanent colostomy was done. The patient very quickly learned to take care of his colostomy, made a good adjustment, and has been steadily employed ever since. He was last seen June 19, 1955, four years after colostomy. His weight had increased from 125 to 185 pounds.

It is impossible to say, with conviction, whether permanent colostomy was unavoidable in this case. In the light of subsequent experience, as noted in the next 3 cases, normal bowel function might possibly have been salvaged. We now know that frequent, carefully performed dilatations, with the finger, and with the proctoscope, if persisted in long enough (until the scar matures and cicatricial contracture ceases) may result in satisfactory bowel function with adequate control, even in the presence of some degree of stricture. As long as an adult sigmoidoscope can be passed without pressure, the aperture is apparently adequate. Dilatations must be done 2 or 3 times a week at first, the interval being gradually increased, and after 8 to 14 months they can be discontinued.

Case 2. C. M. This 11 year old girl was admitted to the Children's Hospital July 30, 1951 with a diagnosis, based on out-patient studies, later histologically confirmed, of congenital megacolon. Since infancy she had been receiving one or more enemas daily, under the care of a scrupulously devoted mother, and was well nourished and normally developed for her age. On Aug. 3, 1951 an abdomino-perineal resection and para-anal anastomosis was performed, using Swenson's technic. Silk sutures were employed in the seromuscular layer of the anastomosis. A single cigarette drain was brought out through the working incision, from the perirectal space.

On the fifth postoperative day minimal fecal drainage around the cigarette drain indicated that a small leak had occurred at the suture line. Since this was the first recognized postoperative leak in our experience, corrective action was not as prompt as it was when encountered in subsequent cases, especially since the drain prevented alarming complications. On the eighteenth postoperative day the leak was visualized through a proctoscope, and appeared so small that an ill-advised attempt was made to seal it off with an indwelling soft thoracotomy tube, inserted through the anus, past the suture line. This appeared to be effective and drainage through the abdominal fistula ceased, but, after 1 week, a recto-vaginal fistula developed, apparently from pressure of the tube at the suture line. A Wan-

gensteen colostomy was then done in the transverse colon. Six weeks later the rectovaginal fistula was repaired, with the colostomy intact. In spite of the diverted fecal stream the repair was unsuccessful, and the fistula recurred, although smaller than before.

In December 1951, 4½ months after the initial procedure, the colostomy was closed, in spite of the rectovaginal fistula, because it was temperamentally difficult for the child to adjust to its presence, and a series of digital and proctoscopic dilatations of the moderately contracted suture line was begun. The interval between these treatments was progressively increased until an interval of 3 months was found to be adequate to maintain normal bowel function. In October 1952, 11 months after the previous attempt, the rectovaginal fistula was repaired again, and again without success. It was decided, then, that further attempts at this repair should be deferred until the patient had reached physical maturity and operation would be facilitated. The patient is now 16 years old (fig. 2). She has not required dilatation for 14 months, and it was not needed at her last examination on March 1, 1956. Bowel function is normal, except for the spill-over from the still patent rectovaginal fistula.

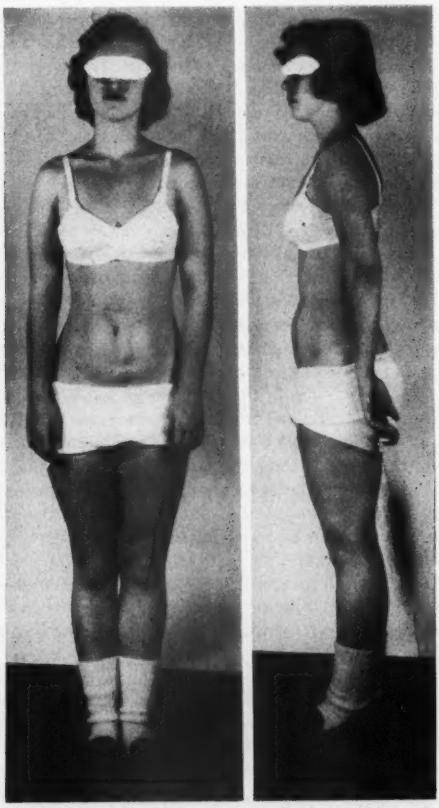

FIG. 2. Photograph of the patient described in Case 2. Although she developed a leak and a stricture at the line of anastomosis, the latter was adequately corrected by persistent dilatations, over a period of about 18 months. She has an adequate passage and has not required dilatation in a period of nearly 2 years. The photograph was made 4½ years after the original operation.

Case 3. J. R. C. This patient was a 3½ year old girl weighing 28 pounds, with typical history and findings of advanced congenital megacolon, subsequently confirmed by histologic examination. On Nov. 14, 1952, a Swenson-Hiatt resection and "pull-through" anastomosis was done, using silk sutures in the seromuscular layer. Resection included most of the descending colon, after mobilization of the splenic flexure. Neither abdominal nor perineal drainage was employed. On the sixth postoperative day a massive "blow-out" occurred at the suture line, with severe pelvic and abdominal peritonitis. Because of the child's precarious condition a tube cecostomy was done, followed, a few days later, by ileostomy. In the next 4 months the patient underwent 7 additional operations incident to the massive infection she had sustained. These included drainage of a large presacral abscess, and several revisions of the enterostomy stomas. After 7 months in the hospital, she was transferred to a convalescent home, with an hepatic flexure colostomy in which the divided ends were completely separated.

Eight months later she was readmitted. Proctoscopic examination and contrast studies showed a persistent epithelialized sinus from the site of the original leak to the healed scar of one of her previous ileostomies. On Jan. 4, 1954, a laparotomy was done, and this sinus tract was excised, leaving the colostomy undisturbed. Re-examination, after another interval of 3 months, indicated that the site of the leak had now healed firmly, and on April 13, 1954 the colostomy was closed. Recovery was uneventful, bowel function was apparently normal, and the patient was sent home on the fourteenth postoperative day.

Four weeks later, and 6 weeks after closure of the colostomy, the original leak in the suture line broke open again, and on May 26 the colostomy was reconstituted as before.

After this, a full year was allowed to elapse. The patient re-entered the hospital in May 1955. All studies were repeated and showed that in addition to considerable rectal stricture, a sinus pocket was still present. The choice seemed to lie between permanent colostomy and the substantial risk of undertaking a completely new pull-through procedure, in the presence of extensive scarring from sepsis and previous operations. This risk was accepted by the parents and, on May 24, 1955, the transverse colon was further mobilized, the previously implanted pelvic segment was coned out (with considerable difficulty) and a new definitive operation was done. On this occasion inverted catgut sutures were used in the seromuscular layer of the anastomosis; recovery was uncomplicated, and after another 2-month interval the colostomy was again closed. The patient was discharged to her home Aug. 13, 1955, 11 days after closure of the colostomy, 2 years, 9 months after her initial operation, and after a total of 15 surgical procedures. After 10 months, there is no stricture and bowel function is satisfactory (fig. 3).

Case 4. G. A. H. This 6 year old boy was admitted to the Children's Hospital Nov. 14, 1952, with the typical history and roentgenologic findings of Hirschsprung's Disease. He also represented a typical example of the Lawrence-Moon-Biedl syndrome (obesity, hypogenitalism, retinis pigmentosa, polydactylism). As a result of this, in spite of his severe megacolon, which had required multiple daily enemas since birth, he was far from malnourished and was, in fact, extremely obese.

Because of his marked colonic dilatation, a three stage resection was recommended, but since he had come from Central America for operation and since the interval between the operations would have required either a prolonged stay in Cincinnati, or several expensive trips back and forth, the parents were insistent on a single operation, if possible. With some misgiving, therefore, and with considerable technical difficulty (because of his obesity and narrow pelvis), on Dec. 1, 1952 resection of the entire descending colon and rectum was done, with para-anal anastomosis, using Hiatt's technic. Silk sutures were used in the seromuscular layer. The operation and the anastomosis were considered technically satisfactory, and following Hiatt's recommendation of that time, a retroanal perineal drain was used in the presacral space. His postoperative course was essentially uneventful and the drain was removed on the sixth postoperative day. On the nineteenth postoperative day, a fecal fistula developed along the course of the perineal drain. Careful examination under anesthesia revealed a 3 mm. leak in the posterior midline, emptying through the drainage tract.

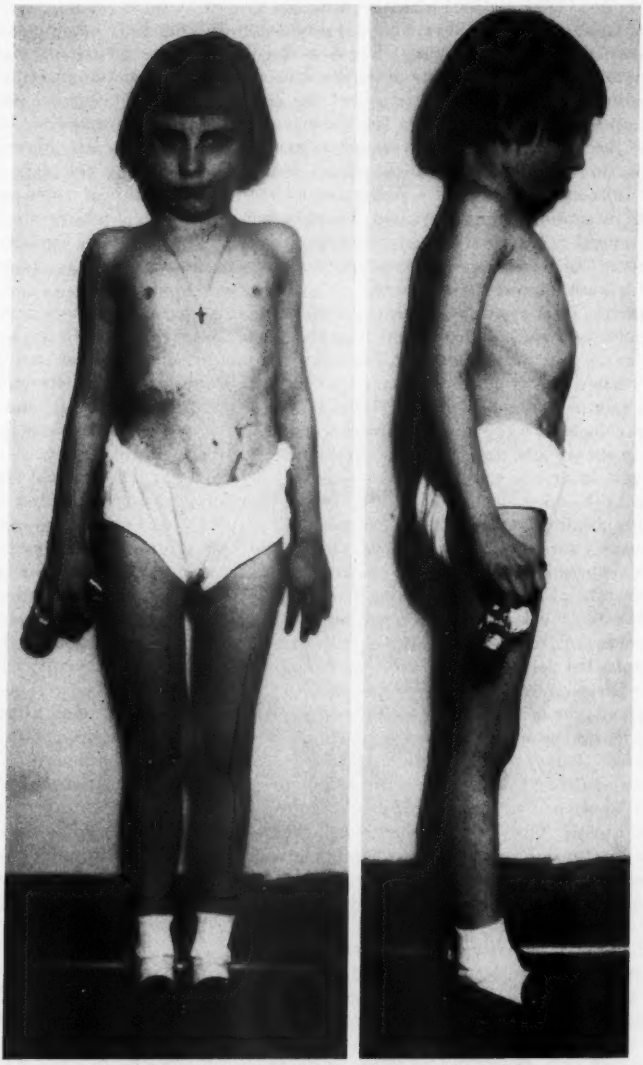

FIG. 3. Photograph of the patient described in Case 3, taken 3½ years after initial operation. She sustained a disastrous breakdown of her suture line, with severe and prolonged morbidity, and has been referred to in a previous publication as an operative failure, with permanent colostomy. However, in May 1955 a second definitive pull-through operation was successfully accomplished. The photograph was made 10 months after this latter operation.

A colostomy was advised, but again, because of economic considerations, it was decided to permit the patient to return to Central America and have the operation performed there. Although several letters were exchanged, and apparently through misunderstandings resulting from the language barrier, a tangential, rather than a completely diverting colos-

tomy, was done. After various unsuccessful measures, and some 22 months after the original operation, the child was returned to Cincinnati, and a completely diverting colostomy was done in the hepatic flexure of the colon on Sept. 23, 1954. Two weeks later, the fistulous tract was coned out locally, to eliminate its now epithelialized lining.

The patient returned to Central America again and 11 months later he re-entered the Children's Hospital, for closure of the colostomy. The fistula had been firmly healed for nearly 10 months. On Aug. 5, 1955 the colostomy was closed, with uneventful recovery. He returned to his home 11 days later and is reported to have remained well, with satisfactory bowel function since then. His ultimate recovery, then, was 3 years, 8 months after initial operation, and he has remained well 8 months since final closure of his colostomy.

DISCUSSION

Out of this group of cases, two have previously been reported as having permanent colostomies. One of these (Case 1) remains in this state. The other (Case 3) has been salvaged and appears to have a satisfactory result, but only after prolonged and exhausting morbidity and many operations. In this instance the second complete pull-through procedure was undertaken with considerable anxiety, in view of the extensive scarring, both from the first definitive operation, and from the severe sepsis and the numerous temporizing operations required to control it. The ultimate favorable result has been gratifying and demonstrates the feasibility of a second definitive procedure following total failure in the first.

All 4 cases serve to emphasize the vital importance of prompt, totally defunctionalizing colostomy at the first sign of a leak in the suture line, whether or not the perirectal space has been drained. If the fecal stream is immediately and completely diverted and an interval of 4 to 6 months (or longer if the leak is a large one) is allowed, for solid healing, continuity can safely be restored, and satisfactory function can be achieved, even in the presence of some degree of stricture. Such strictures require periodic dilatation for a year or more, until fibrous contraction ceases, but if a lumen large enough to permit passage of an adult proctoscope persists, adequate function is possible.

Therefore, although the incidence of such distressing leaks in the suture line can now be minimized by attention to recent technical modifications, the complication, when it does occur, need not render the case unsalvageable. In any considerable series of operations of this magnitude, occasional accidents are unavoidable, and the recognition and management of complications is as important for the well-equipped surgeon as is proficiency in the initial procedure.

MANAGEMENT OF FUNCTIONAL MEGACOLON AFTER SUCCESSFUL OPERATION FOR CONGENITAL MEGACOLON

The recognition of acquired Functional Megacolon as a nosologic unit has important implications with respect to the long-term management of successfully treated Congenital ("aganglionic") Megacolon. For this reason a brief recapitulation of what is meant by this term is pertinent. It cannot be reiterated too often that megacolon, per se, is a symptom and not a disease entity. Dilatation, hypertrophy and ultimate loss of muscular tone are the inevitable result of chronic incomplete colonic obstruction from any cause. Experimental evidence has been adduced which suggests that this response to incomplete obstruction is more pronounced and develops more rapidly during the periods of active growth

in the very young, than it does in physically mature individuals. When obvious organic stricture, most frequently the result (in children, at least) of inadequately or improperly treated imperforate anus, is present, it is easily recognized by digital examination. We have chosen to call this Organic Megacolon, for lack of a better term. The term distinguishes it from Congenital Megacolon in which the underlying cause, (parasympathetic ganglion deficiency and consequent achalasia), is not grossly apparent although it is nonetheless organic.

The third major group of megacolon cases, which has been called Functional Megacolon, is that in which no organic lesion is present, either grossly or microscopically, and in which the dilatation and hypertrophy are the result of chronic fecal impaction alone. The degree of dilatation and hypertrophy, and the existence of mucosal ulceration and chronic "pot-bellied" distention may be so severe that until the dramatic results achieved by removal of the impaction and effective bowel training have been observed, it is sometimes difficult to believe that no organic lesion is present. There can be little doubt that in previous years many of the patients in whom favorable results were achieved by sympathectomy (always accompanied by vigorous medical management) actually fell into this category. The recognition and differential diagnosis of functional megacolon has been discussed elsewhere[5,7] and to repeat it here would needlessly prolong the present discussion. Suffice it to say that, in this community at least, it is so well recognized that most such patients are now treated by the family pediatrician, without surgical referral or consultation.

What, then, has this to do with surgically treated congenital megacolon? The fact is that functional megacolon, pure and simple, may and does occur following satisfactory operation for congenital megacolon, and responds just as well to medical management as does its indigenous counterpart, if it is recognized as such, and the reasons for it are understood. Lack of such recognition and understanding, in the occasional case in which it occurs, may lead to the false conclusion that the corrective operation has been ineffective. The following cases will illustrate the point, after which the mechanism will be discussed.

CASE REPORTS

Case 5. W. C. This patient has been referred to in two previous publications[4, 6] and is well and asymptomatic more than 6 years after definitive operation for congenital megacolon. Certain aspects of his long-term postoperative course were omitted, for brevity, from previous reports, but are emphasized here as being pertinent to the present considerations.

The patient underwent the Swenson operation Jan. 3, 1950, when 2½ years old, and his postoperative course was uneventful. He was kept in the hospital slightly over a month after operation because he came from a remote mountain district where close follow-up supervision was impossible. He left the hospital in robust health, with normal bowel function.

Six months later he was readmitted with distended abdomen, severe emaciation, and every evidence of chronic debilitation. Concern was felt over the possibility that the operation had been inadequate or that a stricture had developed. Rectal examination showed a smoothly healed suture line, without stricture, and a massive fecal impaction.

The impaction was broken up and removed with enemas, and improvement was immediate and striking. Within a few days normal bowel function was restored, the child steadily

gained weight and strength, and after 10 weeks in the hospital he was again in vigorous good health and required neither enemas nor laxatives.

He was sent home again but 2 months later he was again readmitted and the same cycle was repeated. It was learned on this admission that the child's home provided only an unheated outdoor privy, and having become accustomed to the comparatively luxurious toilet facilities at the hospital, he simply refused to move his bowels at home and was not required by his parents to do so. He rapidly developed a fecal impaction, which would persist until his deteriorating condition demanded readmission.

The patient's response to initial enemas and regular bowel habits was again immediate and complete and he was sent home in good condition for the third time after 7 weeks, having been provided with an indoor "potty seat", which apparently was not used.

Inexorably, after another interval of 4 months he was returned. On this occasion, after the initial removal of the fecal impaction, he was transferred to the local Children's Convalescent Home where he remained for 6 months, without ever requiring enemas or laxatives. Meanwhile, his parents were divorced, and when he was returned to his native state he was placed, by the local social agency, in a foster home with other children and with modern toilet facilities. He has remained well ever since, and his physical growth and development have been normal.

Case 6. J. L. A. This white female infant underwent one stage resection for congenital megacolon on Jan. 26, 1954, at 8½ months of age. The diagnosis was histologically confirmed, and the postoperative course was uneventful except for a bacterial enteritis, which developed on her twenty-fourth postoperative day. This was controlled with neomycin and she was discharged in good condition.

She remained asymptomatic and displayed normal growth and development, and apparently normal bowel function for 7 months thereafter, and follow-up examinations showed a smoothly healed anastomosis without stricture.

The following month (eighth month after operation) a series of telephone calls from the family physician reported repeated episodes of obstipation and abdominal distention, and on Sept. 12, 1954, nearly 9 months after operation, she was readmitted to the hospital in what appeared to be acute intestinal obstruction. Rectal examination was negative except for a large fecal impaction. This was easily dislodged and the bowel was readily decompressed with enemas. Although she was now 17 months old, she showed no inclination to walk and her abdominal muscles were noticeably flabby and hypotonic. Social service investigation revealed that the family had become involved in severe domestic difficulties and the child's supervision and instruction had apparently become completely neglected. She was transferred to the Children's Convalescent Home, where a program was vigorously prosecuted to teach her to walk and to encourage vigorous activity. This was combined with closely supervised bowel training. The patient's health was rapidly restored and she remained in the convalescent home for 9 months, during the last 8 months of which her bowel habits, growth and development were normal (fig. 4).

In October 1955, 21 months, after operation, her parents insisted on taking her home. They called for her late in the evening, after she had gone to bed for the night, arousing her from sleep, and an aura of alcoholic breath was noted. The child began to vomit *on the way home* and within a week was readmitted to the convalescent home with distention, obstipation, and recurrence of impaction. She responded to conservative measures again, and in the security and stable environment of the convalescent home she is asymptomatic and requires neither enemas nor laxatives.

Case 7. G. J. M. This white male infant underwent one stage resection for congenital megacolon at 9 months of age, on Feb. 24, 1955. The diagnosis was histologically confirmed, the postoperative course was uncomplicated, and the patient was discharged on the twelfth postoperative day. He did well for a month and was then readmitted with gastroenteritis, which responded to medical management. Rectal examination showed a cleanly healed anastomosis without stricture. The parents were urged to encourage regular bowel habits (the infant was now 11 months old) and to teach him to walk at the earliest possible indication of interest in doing so.

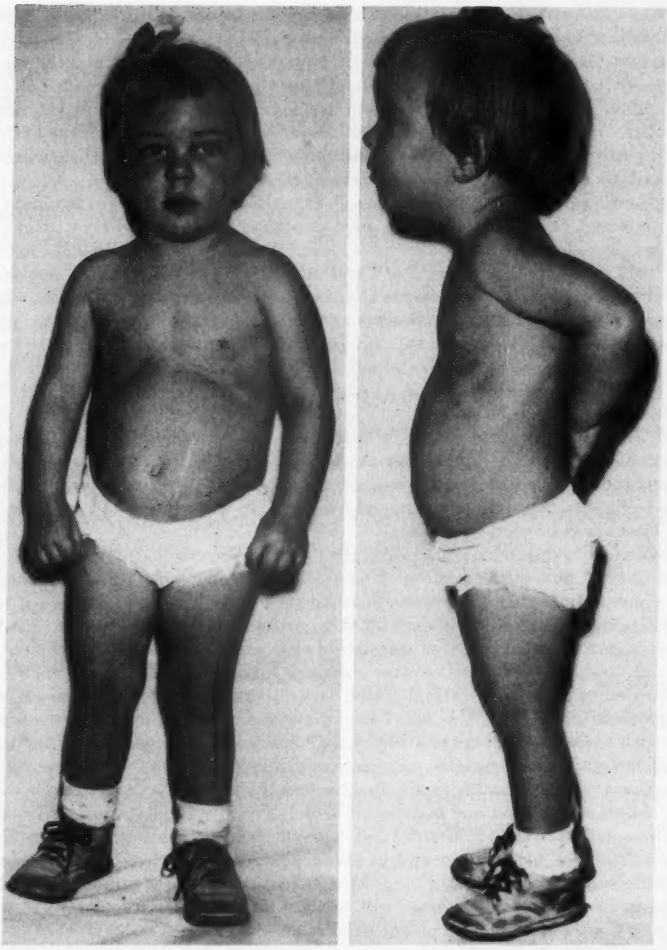

FIG. 4. Photograph of the patient described in Case 6. She is an example of the functional disturbance, described in the text, which can occur as a late complication after successful operation with uneventful recovery. Although her abdominal muscle tone is still somewhat deficient, spontaneous, normal bowel function has been restored by adequate nonsurgical methods.

A month later he was admitted again with otitis media and although there was no fecal impaction, the colon was distended with gas and the abdominal muscles were flabby and hypotonic. When the patient's acute febrile illness had been controlled he was started on mecholyl bromide, and was transferred to the Convalescent Home for bowel training and encouragement in learning to walk. He responded very well and was returned home in the care of his parents after 2 months, with continuation of the same program at home. In August 1955 at the age of 15 months he was robustly healthy and having normal bowel movements. Barium enema on Aug. 18, 1955 showed a distensible colon (residual hypotonia)

which emptied well when the child strained. He was last seen March 27, 1956, 13 months after operation. Rectal examination was negative, and growth, development and bowel habits are normal.

DISCUSSION

There are certain features that these three cases have in common and which have been encountered in less dramatic form in several other instances which, since the pattern is so similar, do not merit detailed summary. In all instances review of the slides from the resected specimens showed that the resection had been high enough and that the proximal segment at the anastomosis contained normal parasympathetic ganglia. As long as compatible diametric size is achieved, no effort is made to remove *all* of the dilated descending colon. Since the innervation is normal, ultimate return of normal function can confidently be expected, and it is believed that no more large bowel should be sacrificed than is absolutely necessary.

This means that chronically dilated and hypotonic bowel is left in place. Failure to achieve regular and complete evacuation not only retards improvement in the tonus of the colon, but actually induces retrogression of any previous progress toward normal bowel tone.

In this connection, several factors must be considered:

A. The development of good abdominal muscle tone in young children is dependent on various forms of exercise such as crying, defecating, crawling, kicking the legs and, finally, walking. Of these the most important is walking, as exemplified by the fact that the spontaneous closure of small umbilical hernias commonly takes place within a few months after the infant begins to walk independently.

In young, preambulatory infants the muscles of the abdominal wall often are not well developed, and the coordinated act of contracting these muscles during defecation has not been learned well. This is especially true of infants undergoing operation for megacolon at 8 to 14 months of age, because prior to this, all bowel movements have been induced by enema, with minimal exertion on the part of the infant.

B. A related phenomenon is the apparent fact that since such infants have been completely dependent on their mothers for every bowel movement, they apparently enjoy the extra attention, concern, and "tender loving care" that this entails. When this special solicitude is withdrawn, after operation, an obvious psychic factor is added to the physiologic components noted in the preceding paragraph.

C. It is widely recognized that functional megacolon, "*sui generis*", that is, independent of previous organic disease and operation, is most commonly seen in children who have been subjected to the psychic trauma and insecurity of disturbed family relationships. So regularly is this true in our own experience, and that of others,[2,7] that the recognition and the adjustment of such difficulties have become integral parts of the medical management of functional megacolon. When these influences are superimposed on the factors referred to in the preceding two

paragraphs, the patient who has undergone an otherwise successful operation can hardly escape the development of this functional disorder.

D. When an intercurrent and unrelated illness such as otitis media, or recovery from gastroenteritis, distracts the mother's attention from regular daily evacuation of the bowels, or when (as in Case 5) there is some specific reason for voluntary retention of stools, even a moderate fecal accumulation can rapidly develop into a true impaction. Unassisted efforts to evacuate this are so painful and frustrating to the child that the difficulty rapidly compounds itself. The hypotonic colon is quickly deprived of any progress it may previously have achieved and the full-blown picture of megacolon may be re-established, as a result of fecal impaction alone. Both the surgeon and the family physician may conclude erroneously that the operation was inadequately performed, or that the procedure is, of itself, unsound.

It becomes apparent, therefore, that both the immediate and the long-term postoperative care of patients undergoing abdomino-perineal resection for congenital megacolon must be based on a clear understanding of the secondary, as well as the primary pathologic physiology. This is expecially important when the operation has been performed on preambulatory infants. In my experience the procedure is technically easiest and best tolerated between the ages of 8 to 14 months. Sometimes it must be done earlier than this when the achalasic segment is long (making control with enemas difficult), or when the mother's aptitude is less than adequate for conservative care at home, and recurrent episodes or acute obstruction compel early definitive operation. Neither should operation be deferred any longer than is necessary to achieve otherwise ideal circumstances. Spontaneous defecation is a voluntary, coordinated act, which must be learned, and the longer the opportunity to practice it is delayed, the harder it is for the child to acquire the necessary skill. Moreover, the sooner the child becomes independent of his mother, with respect to bowel movements, the more likely he is to achieve normal emotional development for his age. These considerations are exceedingly pertinent to the effective surgical care of congenital megacolon.

Before the patient is discharged from the hospital it is the duty of the surgeon to spend enough time with the mother to acquaint her thoroughly with her responsibilities and the reasons for them. She must be urged to "make up" to the child, in some other way, the extra solicitude which the infant has learned to enjoy in connection with the enemas upon which his preoperative physical well-being depended. At the same time she must encourage spontaneous bowel movements by praise and habit training. Above all, she must understand that if an adequate stool is not produced over any interval of 36 to 48 hours, a mild laxative should be given, or an enema, and that the development of an impaction must be avoided at any cost. It must be explained to her that her child is starting off with a handicap of 8 to 14 months or more in the essentially instinctive process of learning to move his bowels spontaneously and that the need for occasional help, in the form of mild laxatives or enemas, does not mean that the operation is a failure. Finally, it is the duty of the surgeon himself, or the family

physician, to see the child and the mother, at regular intervals, to assist and advise in the process of rehabilitation, until normal tone has been restored to the colon and regular spontaneous bowel movements have become an established habit for the child. The length of this follow-up supervision will vary somewhat in accordance with the amount of hypotonic colon and the degree of dilatation of it, that remains after operation, and on the number of setbacks that are permitted to occur in the re-education and rehabilitation period. As a general rule, some degree of follow-up supervision should continue for 3 to 5 years, depending upon the age at which the operation was performed.

SUMMARY AND CONCLUSIONS

The long-term care of infants and children who have undergone "pull-through" operations for congenital megacolon, has been discussed under two general categories—the management of complications arising from technical errors or accidents, and the management of complications arising from improper or inadequate follow-up care of patients after successful operation. Four illustrative cases have been cited in the first, and 3 cases in the second category.

With respect to the first group, it has been shown that the development of a leak in the suture line does not necessarily mean total failure of the operation. Prompt and total diversion of the fecal stream by a suitable temporary colostomy may permit complete healing and subsequent restoration of continuity. Even if a substantial stricture develops, permanent and adequate patency can be restored if regular dilatations are continued long enough, that is until the fibrous scar has matured and further contracture ceases. If these measures fail, it is feasible to perform the definitive operation again, in spite of pelvic scarring, although this is a strenuous procedure and is to be undertaken only when no other course offers any hope of success.

The second group, illustrated by 3 cases, consists of patients who developed functional megacolon as a late complication, after successful operation and uneventful recovery. The reasons for this untoward development are discussed and suggestions are offered for its prevention.

The operation of abdomino-perineal resection with sphincter-preserving para-anal anastomosis, employing the "pull-through" principle of Swenson, is believed to be the only permanently effective procedure for this condition, because it corrects the demonstrable anatomic defect. A technically satisfactory operation with favorable immediate result does not, however, assure uninterrupted progression to permanent recovery unless the predilection toward possible functional megacolon is understood and forestalled. If this complication does occur, intelligent management is not difficult, but failure to recognize it for what it is may lead to unjustified disappointment in the operation itself, or to the erroneous belief that it has been improperly performed.

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TREATMENT OF WOUNDS OF THE HEART: A COMPARISON OF METHODS AND AN ANALYSIS OF RESULTS*

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Patients with penetrating wounds of the heart and the portions of the pulmonary artery and aorta within the pericardium will continue to comprise an important fraction of the group that requires treatment for traumatic conditions of the chest. The significance of this type of cardiac injury is established by the large number of cases which have been reported from centers in the eastern Southern states: there have been 38 reported from Atlanta,[3] 108 have been described in three reports from Louisville,[5,6,7] and there are 65 cases in the literature from Nashville.[4] An earlier report from Cincinnati covered a series of 13 cases,[8] and the present one gives an additional 38 from the General Hospital of this city. Furthermore, it is doubtful if the frequency of this type of wound will diminish during the next few decades. Cardiac wounds of this kind are practically always the result of violent assault and there is little hope that the primitive motives which lead to this crime will be controlled by the forces responsible for the education and protection of the populace.

The writing of Blalock and Ravitch in 1943[2] drew attention again to the possibility of treatment by pericardiacentesis for acute tamponade which develops after penetrating wounds of the pericardium. The practice in this Clinic was altered somewhat following the publication of their results, and during the ensuing 5 years the nonoperative treatment of wounds of the heart was given cautious trial. This report covers all patients who had wounds of the heart who were admitted to Cincinnati General Hospital since 1941. The patients fall into two groups: 14 were managed by the nonoperative method and 24 were treated by exploration of the pericardium and suture of the myocardial or vascular wound. The purpose of this report is to summarize the results obtained by both plans of treatment.

The Resident Surgical Staff have been responsible for the management of all patients in this series. It is doubtful if any other plan for professional responsibility could provide care for this special group of injuries which would be equal to that given by well trained surgical residents. This is true because of the prime importance of speed in diagnosis and therapy for this type of injury. This concept makes it clear, therefore, that resident surgeons must have a complete understanding of the principles involved in the care of patients with this type of wound. The role played by the attending surgical staff is to evaluate critically and disseminate all information on the technics of diagnosis and therapy for these cardiovascular injuries.

There has been no fixed set of rules covering the therapy for heart wounds in this Clinic. Since 1948 the surgical residents have been encouraged to consider

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nonoperative treatment for selected patients with cardiac wounds. The patients with large wounds over the precordium, and those with relatively small wounds accompanied by signs of active bleeding have all had exploratory pericardiotomy. The other patients with the clinical picture of cardiac tamponade, without large wounds of the thoracic parietes, and without active bleeding, have been treated by pericardiacentesis and meticulous observation. No patients were omitted from this report; anyone with this injury who arrived at the Receiving Ward and still manifested the faintest sign of life, was included. In several instances rapid inspection and auscultation were the only diagnostic measures employed. It was necessary to aspirate the pericardial sac or to massage the heart and suture the wound without even the elementary preoperative measures in a small fraction of the cases.

The age of the patients is a partial index of the physical vigor of the group. Out of the entire 38, 34 were between the ages of 21 and 45. There were only 5 females and only 3 white patients. The complication of alcoholism was encountered in 16 of the group. Epilepsy, rheumatic fever and psychosis were the other major pre-existing complications found in 3 different patients.

Injuries to the musculature and skeleton of the thorax were not an important component of the clinical problem. Three-fourths of the patients had only one wound in the chest wall; the remainder had from two to five. Little information was obtained about the assailant's weapon, and this usually was of no material assistance to the surgeon. Only 3 of the patients were wounded by bullets. Preoperative diagnostic studies were limited to measurement of the venous pressure and fluoroscopic examination of the chest. Venous pressure measurements were of some value in the examination of the patients subjected to pericardiotomy, but it is doubtful if more information was obtained by this means than would have been found on careful estimation from the prominence of the superficial veins in the neck and arms. The measurement of venous pressure gave information of vital importance, however, in the group of patients managed by the nonoperative method. An estimate of the severity of cardiac tamponade at the time of the initial examination, and an early indication of recurrence of cardiac compression after the first pericardiacentesis were both made possible by the measurement of the venous pressure. Fluoroscopic examination of the chest and particularly the cardiac silhouette was done in all patients who could be shifted with safety to the fluoroscopic table. Diminution or absence of cardiac pulsations visible to the fluoroscopist proved to be an infallible sign of tamponade. There were 4 patients whose moribund state made it mandatory that the preoperative evaluation be abbreviated. That the diagnosis can be made without special measures, and further that the lives of these patients may not be irretrievable are proved by the fact that 2 of these desparately ill patients were cured

An attempt was made in 8 of the patients to expose the pericardium through an extrapleural approach. A satisfactory anesthetic effect was obtained by means of local infiltration of procaine solution in only 3 out of this group of 8. The plan advocated now is the administration of an ether-oxygen mixture through an intratracheal tube. A simple intercostal incision with division of costal cartilages,

if necessary, is recommended since it requires much less time than the more complicated extrapleural exposure of the pericardium.

A tabulation of the frequency of involvement of the various structures within the pericardial sac discloses facts anticipated through knowledge of the anatomic relations of the ventral aspect of the heart and major vessels. The right ventricle was injured in 12 of the patients and the left ventricle in 6. There was a wound of the base of the aorta in 2 and of the left auricle in an equal number. The right auricle was punctured in 1 patient, and the base of the pulmonary artery was lacerated in 1. Two patients in the group in which exploration was carried out had injury to coronary vessels in association with a wound involving one of the ventricles.

A complete review of the operative procedure in the 24 patients treated by pericardiotomy would not disclose any observations of particular value for their originality. The surgical residents employed steps in technic emphasized by Claude Beck[1] and practiced now by all who deal with wounds within the pericardial space. Interrupted silk sutures were used to close the cardiac and vascular wounds. Procaine solution was applied to the surface of the heart in many of the patients, but the value of this measure is open to question and the current practice is to advise against use of this agent for the control of "*cardiac irritability.*" Manual compression of the ventricles was carried out in 5 patients immediately after the pericardium was opened. The complicating wounds of the diaphragm, liver and gastrointestinal tract were treated according to the established principles of abdominal surgery. At the end of the operative procedures the pericardial sac was left in free communication with the pleural space. The latter was drained through a "*closed*" system for a minimum of 48 hours. Patients were not segregated for special postoperative care but received the same attention given to all after a major operative procedure. Electrocardiography was frequently carried out in the postoperative period, and this furnished evidence of pericarditis in nearly every patient. Nonspecific myocardial damage was reported in the records of 4 patients in the entire series. In all 4 patients there was complete recovery following treatment by pericardiacentesis, and thus there was no opportunity to correlate the extent of myocardial injury that might be apparent at the time of pericardiotomy and the interpretation placed on the electrocardiogram by the cardiologist.

The experience with treatment of 14 patients by pericardiacentesis alone has confirmed several impressions recorded earlier by advocates of this method (table I). In most of the patients the route through which the aspiration needle was inserted was the subcostal one through the angle between xiphoid and costal margin on the left side. In a few instances this was carried out with guidance by fluoroscopy. In the majority of patients however, a satisfactory aspiration was completed with the patient on a stretcher or in bed on a surgical ward. Over half of this small group were relieved of all the signs of tamponade by a single pericardiacentesis. It was difficult, at first, to correlate the dramatic clinical improvement with the small volume of blood withdrawn from some of the patients. Several patients who remained in shock after transfusions had been given, as

TABLE I

14 patients treated by pericardiacentesis

9 required only 1 aspiration
62 cc. average volume obtained on first aspiration. The smallest volume was 8 cc. and the largest was 150 cc.
2 patients unrelieved of tamponade by aspiration

TABLE II

5 deaths in group treated by pericardiotomy

L. A.—moribund on arrival. Laceration of left ventricle
F. N.—moribund on arrival. Laceration of right ventricle
W. M.—Thrombus in pulmonary artery 24 hours after surgery
V. D.—Shock
L. B.—Shock

well as the other standard measures for supportive therapy, regained consciousness and other signs of adequate peripheral circulation within 5 minutes following decompression of the pericardial sac by this means.

There were at least 2 patients in whom pericardiacentesis was inadequate for the treatment of tamponade. In both of these, the surgical residents abandoned their original plan and explored the pericardium. The unrelieved tamponade in 1 patient was caused by an accumulation of clots which were the result of a wound of the base of the aorta. In the other instance of failure of pericardiacentesis the tamponade had resulted from blood which escaped from a large laceration of the left ventricle.

Pericardiacentesis as a temporizing measure was employed in 6 patients during transfer to the operating room or induction of anesthesia. The method of aspiration used in this way may have extended the time available for definitive treatment of the cardiac wound.

There were five deaths in the group of patients treated by sutures of the wounds of the heart (table II). Two of these patients were moribund upon arrival in the Receiving Ward, and the desperate efforts of the surgical resident included exposure of the heart. It may be misleading to include them in this report, especially if it is inferred that a direct comparison is being made between two alternative plans for therapy. The third patient died 24 hours following closure of a right ventricle laceration; a large pulmonary artery thrombus with infarction of the lung was demonstrated at necropsy. The patients in the fourth and fifth cases died within a few hours after injury as a result of the effects of exsanguination before cardiorrhaphy.

Two deaths occurred in the group of patients treated solely by pericardiacentesis (table II). In the case of the first patient, the combination of injuries to the head, both thoraces, the aorta, and the left coronary artery makes it certain that no form of treatment could control all the effects of this trauma. The second death is simply a tragic illustration of too little suspicion relative to the significance of a laceration near the precordium. The necropsy findings suggest that the small laceration of the right ventricle need not have been lethal if a more active plan of treatment had been followed.

TABLE III

Major complications

Aspiration Group (14)		Pericardiotomy Group (24)	
Chronic pericarditis	1	Pleural effusion	9
Pericardial effusion	1	Intracardiac shunt	2
Pleural effusion	1	Hemoglobinuria	1
Auricular fibrillation	1	Abscess, subpectoral	1
	4		13

TABLE IV

Minor complications

Aspiration Group (14)		Pericardiotomy Group (24)	
Wound infection	1	Wound infection	1
Bronchopneumonia	1	Tracheobronchitis	1
		Thrombophlebitis	1
		Atelectasis	1

The hospital course of the survivors was characterized by a high incidence of complications. All the major complications were tabulated and the patients were divided into two groups (table III). Again, the patients were divided according to the plan of therapy employed and the major complications were listed for each division. The chronic pericarditis recorded in the aspiration group did not cause cardiac constriction; it responded satisfactorily to drainage by pericardiostomy. The single instance of auricular fibrillation was encountered in a 53 year old man 3 days after his injury and the cardiologist was able to revert this to a normal sinus rhythm. The two cases of intracardiac shunt which developed in patients in the pericardiotomy group most likely resulted from wounds which penetrated the interventricular septum. Neither patient was disabled enough by this to be convinced of the need for further diagnostic studies. The hemoglobinuria observed in another patient lasted less than 24 hours, and no renal dysfunction followed this.

The minor complications also were tabulated for the two groups (table IV). The conditions listed caused slight prolongation of the period of hospitalization, but none was a threat to the patient's recovery. The patients treated by pericardiotomy seemed prone to develop complications in the lungs and in the pleural space that had been opened. There were 11 such complications in the group of 24. The same complications were encountered only twice in the group of 14 treated by pericardiacentesis. There was no significant difference between the two groups upon comparison of the average length of hospitalization.

SUMMARY

Emphasis is given to the belief that penetrating wounds of the heart continue to comprise a significant problem in many large cities. The vital role of the resident surgical staff in the treatment of cardiac wounds has been pointed

out. A suggestion is given for the supervisory function of attending staffs of all large general hospitals.

Experience in Cincinnati with an additional 38 cases has been surveyed and the fatalities as well as the significant complications recorded. Pericardiacentesis as the method of definitive therapy for tamponade resulting from cardiac wounds has been discussed briefly. Results obtained by this method justify its use in certain patients. It is emphasized, however, that pericardial aspiration is not a substitute for cardiorrhaphy for patients with large wounds near the precordium or with evidence of active bleeding from wounds in the proximity of the heart.

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ONE STAGE EXTRAPERIOSTEAL LUCITE PLOMBAGE IN THE TREATMENT OF PULMONARY TUBERCULOSIS*

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The conventional multistaged thoracoplasty according to the precepts of the late John Alexander[1] has gained universal acceptance as the standard for permanent collapse therapy in the treatment of tuberculosis. However, because of the obvious disadvantages of a multistaged procedure, numerous operations have been devised whereby the same effective collapse can be obtained in a single stage. Most of these procedures have utilized some type of material (termed a plombage) to prevent paradoxical motion of the chest wall and underlying lung, so that pulmonary function would not be impaired.

Tuffier[11] was the first to introduce extrapleural pneumonolysis in 1891. In this operation, the parietal pleura is dissected off the chest wall over the apex of the lung without entering the pleural cavity, so that the lung, covered by two layers of pleura, is permitted to collapse. In all procedures based on this method of collapse, some type of pack or plombage material has been used to fill the space thus created between the chest wall and parietal pleura, in order to maintain the collapse and prevent paradox. Numerous materials have been used with varying degrees of success. Air, oil, paraffin,[5] muscle, fat, gauze, wire mesh, rubber (in the form of sheeting and air-filled bladders)[4], Fiberglas[3,6], nylon sponge[7], and Lucite spheres[11,12,13] have all been given a trial. In many instances where these materials were used in extrapleural collapse, the intial results were encouraging, because the loss of respiratory function was minimal, and the collapse obtained was excellent. Unfortunately, the incidence of undesirable complications was considerable. In some of these, the material itself had inherent disadvantages. Rubber, gauze, and paraffin provoked severe foreign body reactions; fat and muscle atrophied[8, 13]. But regardless of the kind of plombage material used, bronchopleural fistulas and infections of the extrapleural space were among the most frequent and serious complications reported[2, 10]. Fistulas resulted from perforation of the plombage into the underlying lung, particularly in cases of peripheral cavitation. Fundamentally, the disadvantage of greatest significance in all extrapleural procedures is the fact that the plombage and the collapsed lung are separated only by a thin partition consisting of two layers of pleura. The presence of underlying disease, coupled with deficient blood supply, renders the pleura vulnerable to pressure necrosis and perforation[15]. Worthy of consideration also is the theory that interruption of the mediastinal lymphatics produced by such operative procedure may be responsible for infection of the extrapleural space where no demonstrable fistula can be found[3]. Strieder and

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Gaensler[9] have concluded that subpleural cavitation is an absolute contraindication to extrapleural pneumonolysis.

To obviate these disadvantages, extraperiosteal Lucite plombage was devised and first reported by Woods et al. in 1950[15]. In a more recent publication by Woods and Buente, the results of this operation in 244 cases from the Overholt Thoracic Clinic were reported[14]. In this procedure, an additional pad of tissues consisting of periosteum stripped from the ribs and the intervening intercostal muscles is interposed between the plombage and the collapsed lung. This layer of tissues, which has a rich blood supply from the intact intercostal vessels, apparently acts as a well-vascularized cushion between the spheres and the lung, so that the effects of pressure are minimized. Hollow Lucite spheres, first used by Wilson[11, 12, 13] in 1946 for extrapleural plombage, are used because they most closely fulfill the requirements of the ideal plombage material. They are nonirritating, light in weight, solid, with a smooth nonporous surface, and are relatively inexpensive. The extraperiosteal operation, as originally devised, consisted of two stages. At the first stage, the required number of ribs was stripped to effect the collapse, and the Lucite spheres were inserted. At the second stage, 2 to 6 weeks later, the segments of ribs previously stripped were resected and the spheres were removed, thus producing the same end result as conventional thoracoplasty. Because serious complications were extremely rare, the second stage was later dispensed with after a fair trial, and the spheres were left as a permanent pack, so the entire procedure is now done in a single stage. The first permanent extraperiosteal Lucite plombage reported in the literature was performed by Woods[14] in June, 1949. We can see no real objections to leaving the spheres in place indefinitely. Persistent cavitation under the plombage, or infection of the extraperiosteal space are considered the only indications for removal of the spheres.

Indications. When resection can be performed safely and adequately, it is undoubtedly to be preferred. However, when extensive disease or other contraindications preclude this form of surgical treatment, we believe that one stage extraperiosteal Lucite plombage is the procedure of choice in cavitary disease. The exact indications for the use of extraperiosteal collapse are still somewhat fluid at the present time. The main indication is extensive bilateral disease with cavitation in one or both apices[14]. However, since experience has proved that this procedure is much better tolerated than staged thoracoplasty, the scope of indications has gradually been extended to include those patients who are poor surgical risks, not only because of extensive disease, but also because of impaired respiratory function, advanced age, and/or concomitant diseases.

Procedure. All but 1 of our cases have been done under general anesthesia with endotracheal intubation. This one exception will be discussed subsequently. The patient is placed in the lateral position, and a routine parascapular thoracoplasty incision is made and carried through the chest wall musculature to the rib cage (fig. 1). The scapula is elevated and retracted, and the serratus anterior and scalenus posticus muscles are divided close to their attachments to the

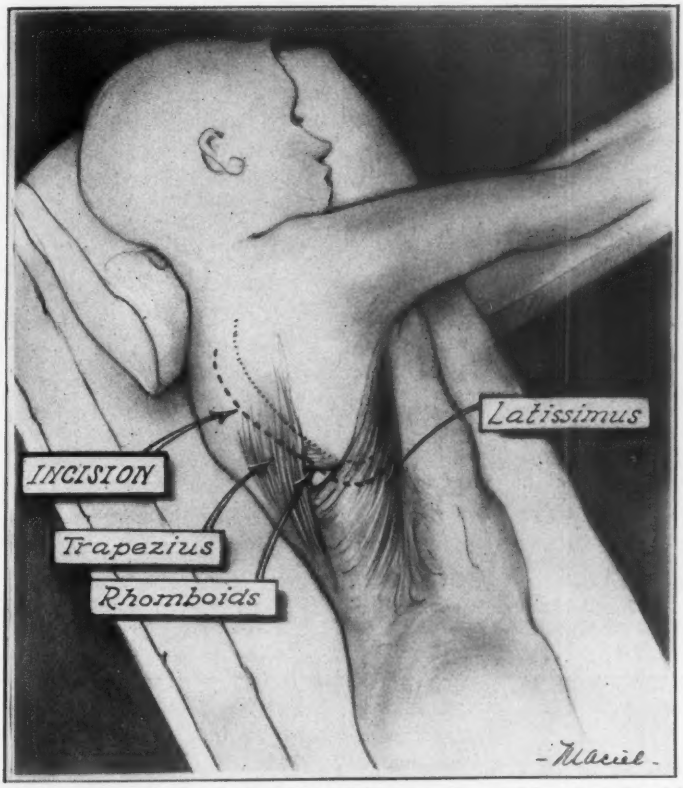

FIG. 1. Diagrammatic sketch showing position of patient and location of incision

second rib. The periosteum is stripped from the posterolateral portions of the required number of ribs, beginning at the midpoint of the proposed collapse, and proceeding alternately upward and downward with successive ribs (fig. 2). It is thought that less danger of tearing the pleura is incurred in this manner[7]. The first rib, which is dealt with last, is denuded of periosteum on its undersurface only. The muscle attachments to its superior aspect are left intact to prevent escape of the spheres through the thoracic inlet (fig. 3). A limited apicolysis is accomplished in this manner, but care must be taken not to continue the dissection downward on the mediastinal surface for more than a centimeter or so. Frequently this can be done with surprising ease, and if carried too far, may permit a thick-walled cavity or one surrounded by indurated lung to be displaced inferiorly without collapsing. The paraspinal muscles are elevated from the posterior portions of the ribs, and the periosteal stripping is carried posteriorly on the medial aspect of the ribs to the rib heads. Taking care to preserve

FIG. 2. After the scapula is retracted and the muscular attachments to the second rib are divided, rib-stripping is begun.

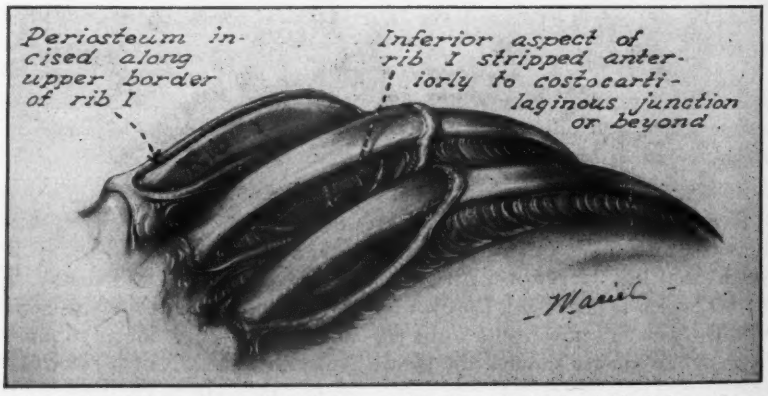

FIG. 3. Undersurface only of the first rib is stripped and limited apicolysis is performed.

the neurovascular bundles, the intercostal muscles are separated from the paraspinal muscle group, and are partially divided at about the level of the transverse processes (fig. 4). The soft tissues can then be stripped back easily by finger dissection to the level of the rib heads (fig. 5). Development of the para-

spinal gutter thus is completed. Final tailoring of the collapse is accomplished by stripping the periosteum from the anterior portions of the ribs as far forward as desired. Usually, the first rib is stripped past the costochondral junction almost to its articulation with the sternum; and progressively shorter segments or the remaining ribs are deperiostealized, tapering the inferior portion of the collapse posteriorly, as in conventional thoracoplasty. After hemostasis is

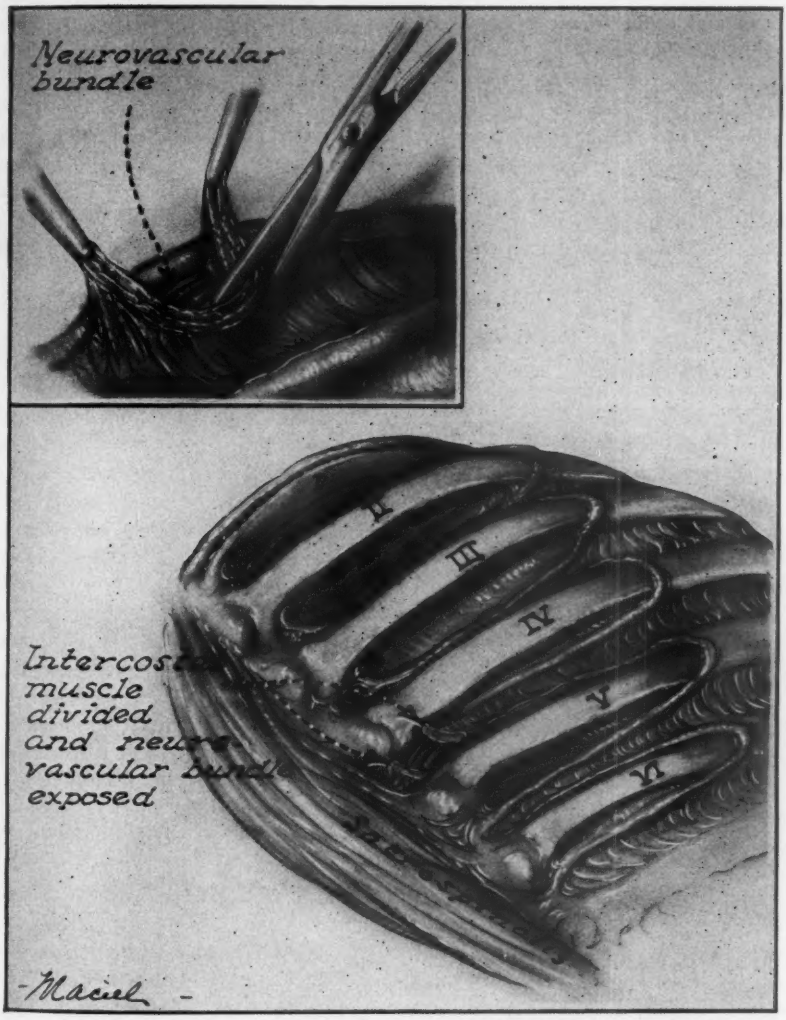

FIG. 4. Beginning development of paraspinal gutter by dividing the intercostal muscle.

secured, the operative area is thoroughly irrigated with saline solution, and Lucite spheres, 1¼ inches in diameter, are then inserted between the denuded ribs and the extraperiosteal tissues. Usually, a row of spheres is lined along the paravertebral gutter first, so that good collapse is insured in that area. This is

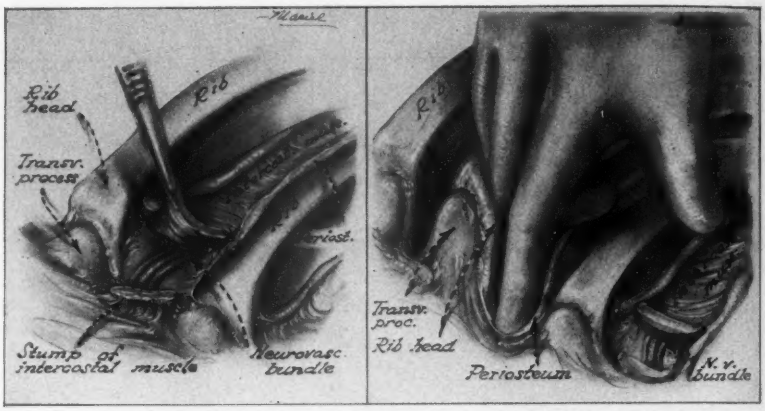

FIG. 5. Completion of development of paraspinal gutter to level of the rib heads

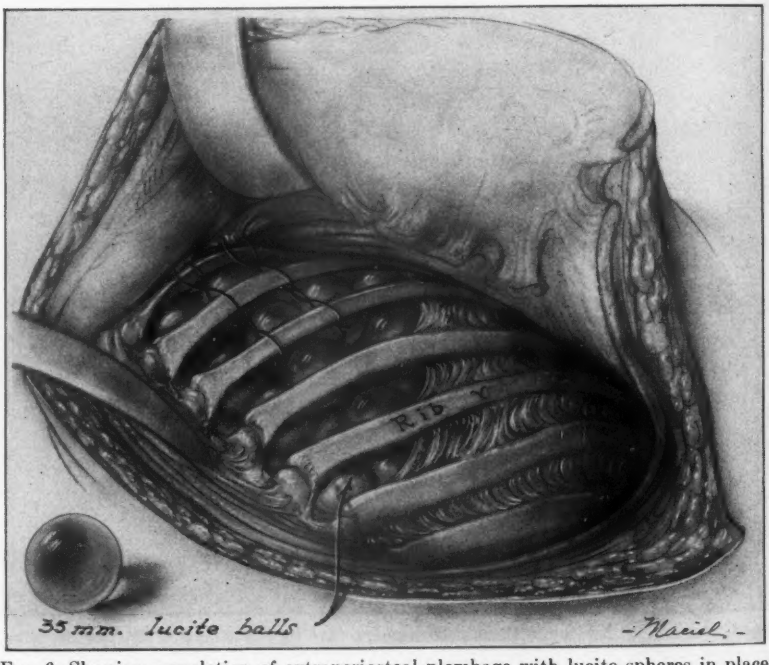

FIG. 6. Showing completion of extraperiosteal plombage with lucite spheres in place

important, not only because this area is frequently the site of cavitation, but also because of the well known propensity of posterior cavities to recede into the gutter following thoracoplasty. The remaining extraperiosteal space is then filled snugly with spheres. Two or 3 sutures of no. 1 chromic catgut are inserted at more or less equidistant intervals into the muscle attachments and periosteum on the superior surface of the first rib, and are tied to successive lower ribs in a lattice-like pattern to prevent possible extrusion of the spheres (fig. 6). A solution of penicillin and streptomycin is deposited in the space, and the chest wall is closed in layers without drainage, using interrupted silk sutures.

Several points concerning this procedure warrant further elaboration. The extent of collapse required in a given case is determined preoperatively from the roentgenograms. Posteroanterior stereo, lateral and oblique views, and occasionally laminography are used to locate cavitary disease accurately. From a study of these films, the number and lengths of ribs to be stripped are decided upon. The segments of individual ribs to be deperiostealized are noted in relation to several arbitrary reference points such as the costochondral junctions, and mid- and posterior axillary lines, which serve as convenient guides in determining the anterior limits of the collapse at the operating table. It should be emphasized that rib-stripping does not have to be as extensive as in staged thoracoplasty. The reason for this is that a more selective collapse can be obtained by this procedure because of a moderate compressing effect exerted by the Lucite plombage. If stripping is carried to the extent needed to produce satisfactory collapse by ordinary thoracoplasty, more collapse than desirable may be produced by this method. By the same token, care must be taken not to pack the balls into the extraperiosteal space too tightly, or again, too much collapse may be produced. The snugness of the pack is determined to some extent by the consistency of the underlying lung; if the lung is firm and collapses poorly when the rib stripping is completed, more compression may be needed to effect cavity closure than if the lung is soft and collapses easily. It has been our observation that those unfamiliar with the procedure tend to produce more collapse than needed. The temptation to "*add another ball*" where space can be found to place it, is great.

Advantages. One stage extraperiosteal Lucite plombage has a number of advantages over multi-staged thoracoplasty. The entire procedure is accomplished in a single operation; as high as 10 ribs have been stripped on occasion, in one stage[14]. Because of the plombage, the dangers of paradox are avoided, and since no flaccidity of the chest wall results, patients can cough effectively, and experience little difficulty in raising sputum postoperatively. As previously noted, more selective collapse can be achieved by this procedure, and particularly in the paraspinal gutter posteriorly, better collapse is insured, due to the compression exerted by the spheres. This is particularly helpful in closing thick-walled cavities, and those surrounded by firm, indurated lung. The incidence of serious complications is extremely low. Lastly, no deformity is produced because no ribs are resected.

Present Series. Since Aug. 7, 1953, 45 one stage extraperiosteal Lucite plombage

procedures have been performed on 40 patients at Dunham Hospital. Five patients had bilateral operations.* Fourteen of these patients were 50 years of age or older, the oldest being 59 and the youngest 16, with an average age of 42.8 years. There were 24 males and 16 females. All had had positive sputum on smear at some time preoperatively, and all had received antibiotic therapy, consisting of streptomycin with isoniazid, para-aminosalicylic acid (PAS), or both, for at least 9 months prior to operation. All had bilateral disease.

Nine patients in this series of 40 cases had diabetes. One patient had had a previous contralateral lobectomy for cavitary disease, and 7 had other procedures such as pneumothorax, pneumoperitoneum, or phrenemphraxis at some time before operation.

There was one death in the immediate postoperative period (up to 60 days). This was a 51 year old diabetic male with a history of proved myocardial infarction, who developed another infarct and died 45 days after operation. There were two late deaths, one due to homologous serum hepatitis, and one due to nontuberculous bronchopneumonia.

Fifteen of the 40 patients had negative sputum on smear immediately prior to operation, a fact which reflects the long periods of antimicrobial therapy all had received preoperatively. Of the 37 patients still living, 4 (all unilateral plombage cases) had persistent positive sputum after operation. One of these has since become negative following further drug therapy, removal of the plombage, and ipsilateral pneumonectomy. In those patients who had positive sputum immediately prior to operation, a sputum conversion rate of 84 per cent was obtained by extraperiosteal plombage alone. The follow-up period for the entire series varied from 7 months to 2¾ years. Only 3 patients have been observed for less than 1 year.

Complications. Fluid which forms in the plombage space has required at least one aspiration in the early postoperative period in all patients. Usually, formation of fluid ceases within 10 to 14 days. Fluid which is aspirated is routinely cultured. In only 1 patient, a positive culture was obtained which yielded an unidentified gram-positive rod. However, repeat cultures became sterile after instillation of antibiotics into the plombage space. No instance of migration of

* In one patient, a 5 rib extraperiosteal plombage was performed for cavitary disease. Contralateral lobectomy was done later for localized disease, and following this, a 3 rib plombage was performed to obliterate a persistent apical air pocket.

Duration of Disease		Size of Cavity		Number of Ribs Stripped	
Age	Number of patients	Size of cavity	Number of operations	Number of ribs	Number of patients
Less than 2 years	11	4 cm. and over	15	3	1*
2 to 4 years	11	Less than 4 cm.	29	4	5
4 to 6 years	10			5	13
Over 6 years	8			6	21
				7	5

the spheres has occurred. Pleural tears were produced in 5 patients. Such tears, unless very minute, usually are noted at the time of surgery, and the resultant pneumothorax is aspirated at the conclusion of the procedure. In any event, each patient is checked by roentgenogram immediately after operation. Pleural effusion, which responded to one aspiration, occurred in 3 patients in whom the pleura was accidentally torn. A Horner's syndrome on the side of operation, which disappeared after several weeks, occurred in 1 patient. Partial demineralization of the denuded ribs, visible on roentgenogram, occurs in all cases, but this has not resulted in any complications.

CASE REPORTS

Two case reports will be presented to illustrate the type of problems in which extraperiosteal Lucite plombage can be successfully applied.

Case 1. G. B., a 46 year old white man, was first admitted to Dunham Hospital in April 1944, with caseous bronchopneumonia, cavitation in the apex of the left lung, and tuberculous laryngitis. Shortly after admission, he developed bilateral pleural effusions, which gradually subsided after repeated aspiration. Pneumothorax was instituted on the left, but was discontinued after a year because of massive pleural effusion. His condition gradually improved, and he was discharged as arrested in July 1946. In 1947, he underwent a nephrectomy for tuberculosis, and was readmitted to Dunham Hospital in November 1948, with positive sputum. Roentgenograms showed cavitation in the right apex, nodular disease in the left lung, and bilateral pleural thickening. During this admission his course was complicated by the occurrence of multiple cold abscesses on the right chest wall; and a hernia developed in his nephrectomy scar. His sputum became negative on streptomycin and para-aminosalicylic acid, (PAS) therapy, and he was again discharged in October 1950. He was admitted to the hospital for the third time in February 1952 because of exacerbation of disease with cavitation in the apex of the right lung, and positive sputum (fig. 7A). During this admission he developed recurrent severe headaches, and a diagnosis of Meniere's syndrome was made. Peptic ulcer was suspected in early 1953 but was not definitely proved. He was treated with long-term streptomycin-isoniazid therapy, but his sputum remained positive and cavitation in the right apex persisted. The patient was dyspneic on

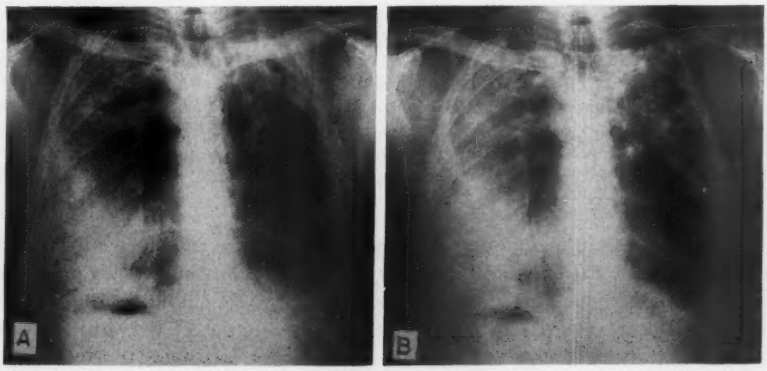

FIG. 7A. Case 1. G. B. Roentgenogram showing cavitation in apical portion of right lung and bilateral pleural thickening.

FIG. 7B. After right extraperiosteal plombage

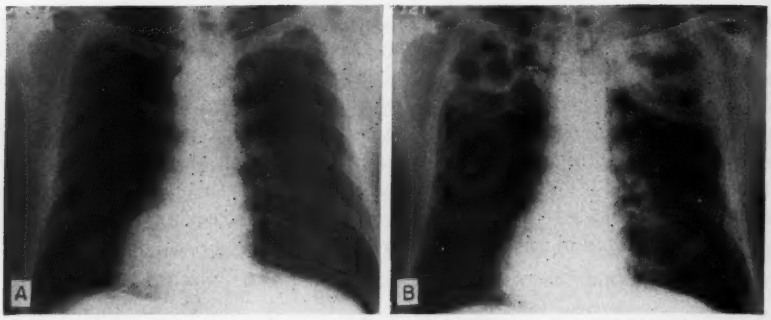

FIG. 8A. Case 2. F. R. Roentgenogram showing bilateral cavitation and scattered fibronodular disease.

FIG. 8B. One year after bilateral plombage. Sputum negative

mild exertion, and preoperative breathing studies showed a vital capacity of only 1200 cc. Maximum breathing capacity was 66.7 liters/minute, with a predicted MBC of 111.2 liters/minute. Blood urea nitrogen was elevated slightly above the upper limits of normal. Because of the patient's limited respiratory reserve it was elected to do the procedure under local anesthesia. A five rib extraperiosteal Lucite plombage was done on the right on Oct. 28, 1953 (fig. 7B). At operation, the lung was found to be markedly indurated, and it collapsed very little after the ribs were stripped. Ten Lucite spheres were inserted into the plombage space, using considerably more compression than usual. He had a remarkably smooth postoperative course, and his sputum became negative on smear of the concentrate shortly after operation, and has remained so up to the present time. His dyspnea on exertion was subjectively improved, but unfortunately function tests were not repeated postoperatively. At present, 28 months after operation, he is asymptomatic except for dyspnea on moderate exertion, and conducts a small business which entails light work.

Case 2. F. R., a 52 year old white diabetic man, was admitted to Dunham Hospital in December 1949, with bilateral apical cavitation (fig. 8A). Although he had received a 50 day course of streptomycin and para-aminosalicylic acid for tuberculous laryngitis prior to admission, his sputum was still positive on smear. He was treated with a long course of streptomycin with PAS and isoniazid, but his cavitary disease persisted, and his sputum remained positive. A six rib extraperiosteal Lucite plombage was done on the left on Feb. 2, 1954. Following this, his sputum continued intermittently positive, and a five rib extraperiosteal plombage was done on the right on May 25, 1954 (fig. 8B). This resulted in conversion of his sputum, which had remained consistently negative on smear of the concentrate. At present, 22 months after the second operation, he is working full time as a clerk. Results of function studies preoperatively were: vital capacity 4397 cc., maximum breathing capacity 138.7 liters/minute. Repeat studies 4 months after the second plombage showed a decrease in vital capacity of only 473 cc., and a decrease in MBC of only 4 liters/minute, a loss of less than 3 per cent.

These rather limited function tests which have been done on all patients, demonstrate very little loss of respiratory function as a result of this procedure. Recently, we have conducted more elaborate studies, including bronchospirometry, on all patients prior to operation, but the number of patients on whom postoperative studies have been performed is as yet too small to be of significance.

DISCUSSION

There has been considerable unfavorable criticism of this procedure, most of which we believe to be unjustified. It is thought that such criticism stems from a variety of reasons. But a large part originates from two sources—one, confusion of extraperiosteal plombage with the extrapleural operation, an apparent misconception that these two procedures are identical, which they are not; second, failures due to lack of appreciation of the basic technical points essential to the successful outcome of the extraperiosteal procedure. These, we have tried to emphasize above.

CONCLUSION

The results in this series of cases have been most encouraging. Extraperiosteal Lucite plombage is a safe and satisfactory method of obtaining permanent collapse in a single stage. It is of particular value in those patients who are poor risks by virtue of extensive disease or associated conditions, and as such would otherwise be denied the benefits of surgery. Consequently, this procedure deserves a place in the armamentarium of the "*tuberculosis surgeon*", and warrants more extensive trial.

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CALCIFIED SUBDURAL HEMATOMAS IN CHILDHOOD: REPORT OF TWO CASES*

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The frequency and importance of chronic subdural hematomas in infancy and childhood are now widely appreciated among general practitioners, pediatricians, and neurosurgeons. Such lesions were first recognized, however, as late as 1930, and during the past 15 years most of the present knowledge concerning incidence, clinical symptomatology, surgical management, and late effects has been accumulated.

MacLean and Levy (1955)[6] collected 24 cases of calcification within chronic subdural hematomas in all age groups and added 1 of their own. Among these 25 cases, only 2 occurred in children below the age of 12 years. In 1930 Goldhahn[3] reported the first such lesion in a boy of 11 years and the hematoma was successfully removed. The other was described briefly by Ingraham and Matson[5] in their classical review of 98 cases of subdural hematoma in infancy. The patient, a 4 month old infant, apparently had a calcified cephalohematoma in the right parietal region. The authors stated that a "calcified hematoma was removed from the right subdural space", but the roentgenologic and histologic pictures were not reported. Because of the extreme rarity of these lesions in the pediatric age group, the following two cases are presented.

CASE REPORT

Case 1. B. S., a 9 year old Negro girl was admitted to the hospital on May 17, 1954 because of fever and convulsions. Five weeks prior to admission she complained of headaches which followed a streptococcal pharyngitis. Two days before admission she vomited and on the day of admission vomiting recurred and was followed by a convulsive seizure. The seizure consisted of rigidity, turning of the head and eyes to the right, and aphasia.

Past history revealed that at age 5 months she had been hospitalized because of vomiting and irritability and signs of meningeal irritation had been present. A spinal tap had been unsuccessful but subdural taps showed large collections (120 ml.) of dark fluid under increased pressure. Bilateral craniotomies had been performed with removal of subdural membranes. Postoperatively the signs of meningeal irritation subsided and no evidence of bacterial meningitis was ever obtained. Following the craniotomies subdural taps were performed on 5 occasions and subdural accumulations were still present at the time of discharge.

At age 4 years the child was seen again because of a head injury and at that time skull roentgenograms were normal but her mental age was approximately $2\frac{11}{12}$ years.

Physical examination showed a well developed girl of normal size (64 lbs.) who was in coma on admission. Nuchal rigidity and symmetrical hyperreflexia were present. Lumbar puncture revealed increased pressure and 250 white cells but no organisms were grown on culture. On empirical antibiotic treatment she improved. During the hospitalization routine roentgenograms of the skull revealed linear calcification surrounding a subdural mass on the left side (fig. 1). Following recovery from the "meningitis" pneumoencephalography demonstrated symmetrical flattening of the lateral ventricles from above without significant displacement of the ventricular system (fig. 1).

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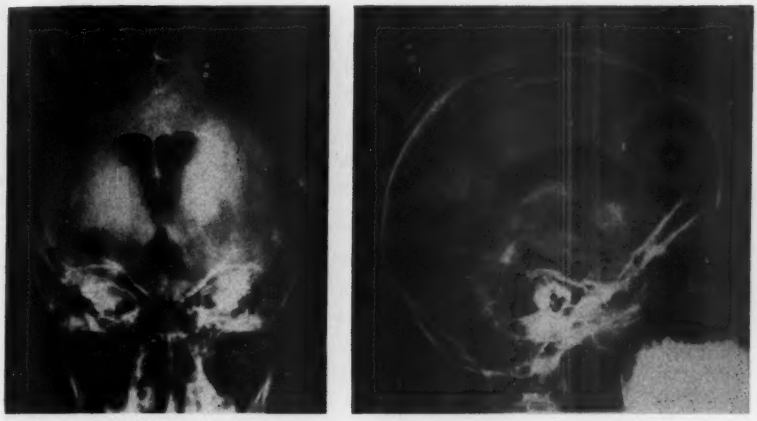


A B

FIGS. 1, A & B. Case 1: Anteroposterior and lateral roentgenograms following introduction of air into subarachnoid space. The sacular calcification over the left hemisphere, extending throughout the fronto-parietal region is seen. The ventricular system is flattened from above on each side, indicating the presence of symmetrical lesions. Note the complete absence of calcification on the right side. Note also the absence of secondary skull changes except for possible thinning of the bone in the left parietal region. The silver clip remains from craniotomy performed in infancy.

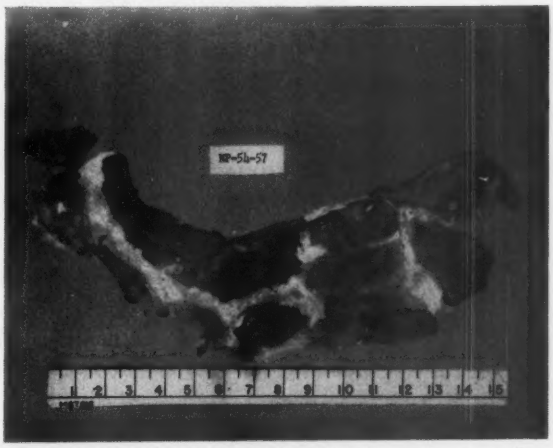


FIG. 2. Case 1: Photograph of reconstructed subdural hematoma sac. Removal was done piece meal and the fragments reconstructed on wax.

First operation: On June 3, 1954 a left fronto-temporo-parietal craniotomy was performed. The dura was easily stripped from the outer surface of the calcified subdural mass. From within the mass approximately 15 ml. of xanthochromic fluid was aspirated. The subdural sac extended medially to the falx and beyond the extent of the bony and dural openings anteriorly and posteriorly. It was removed piece meal and consisted of inner and outer calcified membranes 3–5 mm. in thickness (fig. 2). The inner layer was easily separated from the cortex which was atrophic in appearance.

Second operation: Aug. 25, 1954 a right craniotomy revealed thickened vascular mem-

branes over the hemisphere, similar in extent to the calcified membranes on the left side. The underlying cortex was atrophic and the pia-arachnoid thickened.

Subsequent course: Two months later the child returned to the hospital with evidence of meningitis. No organisms were recovered from the spinal fluid but while hospitalized a right hemiparesis developed and an abscess in the left fronto-parietal region was found. Repeated tapping was done but on one occasion an intracerebral hemorrhage was precipitated. Despite evacuation of the hematoma she has remained hemiparetic. For this reason it has been difficult to evaluate her progress resulting from removal of the subdural hematomas.

Several aspects of this case are of interest. Aside from the problems relating directly to the subdural hematoma it should be noted that her first hospital admission in infancy was accompanied by signs of meningitis. Nine years later another episode of meningitis occurred and finally led to the discovery of an intracerebral abscess. How long the abscess had been present is, of course, conjectural. The lack of roentgenologic evidence on pneumoencephalography and the inability to recover organisms from the spinal fluid led to speculation that the meningeal signs were due to spillage of the contents of the subdural accumulations. Mosberg and Smith[7], however, have emphasized that calcified chronic subdural hematomas may remain entirely asymptomatic for prolonged periods of time and that the appearance of signs of intracranial disturbance in the presence of such a hematoma should arouse suspicion concerning a second lesion.

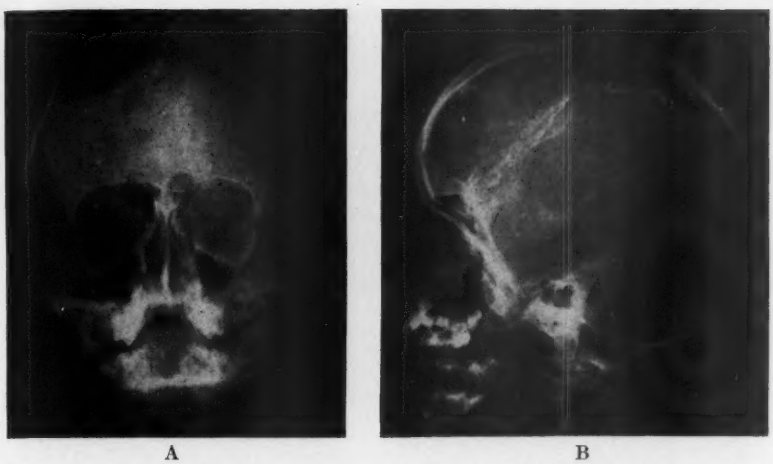
There seems to be no doubt that the hematomas, one of which eventually calcified, were sequellae to those present in infancy. Although there was at least one subsequent head injury, it was noted at that time that she was mentally retarded. Retardation of mental development, with or without convulsive seizures, is recognized as the most common result of long-standing subdural accumulations in childhood.

It is of considerable importance that roentgenograms of her skull at no time showed changes which Davidoff and Dyke[2] have associated with chronic subdural hematoma in childhood. If calcific deposits had not been present there would would have been no roentgenologic or specific clinical evidence of the lesions. One may infer that the lack of changes which are believed to be related to expansion of the hematoma with erosion or enlargement of normal cranial landmarks indicates a true restrictive influence of this lesion on the brain. Moreover, the restriction was symmetrical despite the striking difference in character between the walls of the respective hematomas.

CASE REPORT

Case 2. T. F., an 8 year old white girl was admitted to the hospital on Sept. 14, 1954 following a mild head injury. The past history revealed that at 2 years of age she had been dropped on her head. There was no immediate ill effect of the injury. The mother recalled, however, that afterward the child's head did not seem to grow correctly and she began having occasional convulsive seizures.

Physical examination revealed a girl of very small stature for her age. The head showed an abnormal configuration with foreshortening in the anteroposterior diameter, an increased biparietal dimension, and a flattened broad forehead. She was extremely retarded mentally and was able to say only a few words. Motor activity did not seem to be retarded



A B

FIGS. 3, A & B. Case 2: Anteroposterior and lateral roentgenograms of skull. Bilateral calcified hematomas are confined almost entirely to the frontal and temporal regions. Note thickening of the calvarium in the frontal and occipital areas, marked thinning in the parietal regions, foreshortening and increased breadth of skull, shallow anterior fossa and marked distortion of the skull base, elevation and poor delineation of sphenoid wings, extreme enlargement of the temporal fossae bilaterally.

correspondingly and there was no localizing neurologic deficit. Vision was grossly defective and the discs were pale.

Roentgenograms of the skull showed a "brachycephalic" configuration (fig. 3). The frontal fossa was shallow and the temporal fossa widened and deepened. There was generalized thickening of the bones of the calvarium with localized thinning in the parietal areas. Intracranial calcification was present bilaterally outlining subdural masses which were thickest in the frontal regions. Bone survey showed no evidence of previous syphilis or rickets.

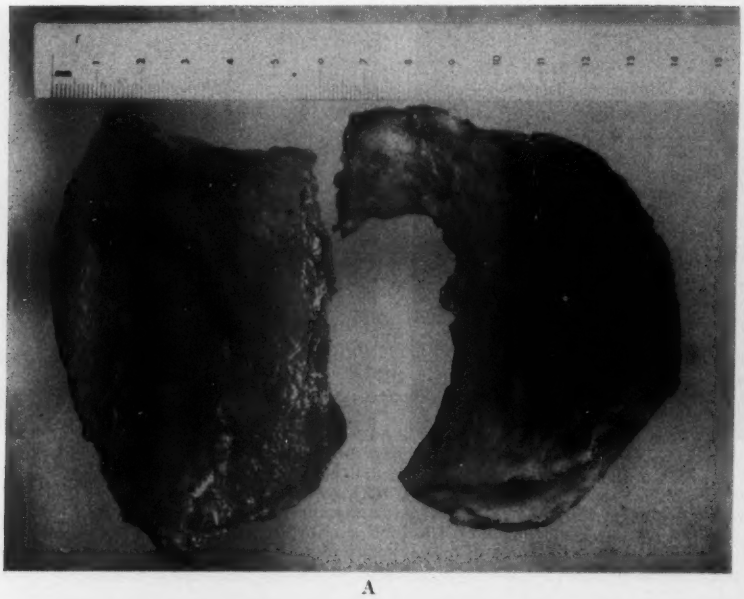
Lumbar puncture revealed a normal pressure and clear fluid with a protein content of 19 mg. per cent. Electroencephalogram was interpreted as showing slow dysrhythmia without localizing signs.

First operation: On Sept. 24, 1954 a left frontal osteoplastic craniotomy was performed. The dura was thin but was easily separated from the underlying calcified membrane. Two separate calcified sacs were present, each containing thin greenish fluid in which were suspended fine crystals resembling cholesterin crystals. The larger sac extended to the falx medially and communicated through an opening in the falx with the cavity of the hematoma on the right side. The 2 sacs on the left were removed entirely (figs. 4 A & B). The underlying frontal lobe was markedly compressed but otherwise was normal in appearance.

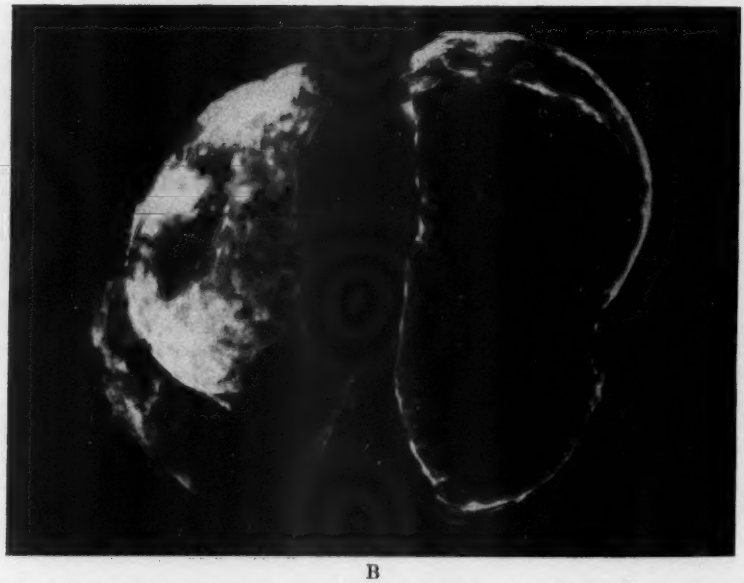
Second operation: On Oct. 27, 1954 a right frontal craniotomy revealed a single large calcified mass similar in size to those on the left (fig. 4B). It was removed to the midline and the superior longitudinal sinus was noted to be obliterated throughout the exposed portion.

Subsequent course: Following the second operation an infection developed at the operative site and eventually necessitated removal of the bone-flap and subsequent tantalum cranioplasty.

Immediately following removal of the calcified hematomas she could not be scored on Stanford-Binet testing. Nine months later her mental age was scored as 3 years, 1 month. During that same period of time there was striking improvement in her general physical growth and some apparent increase in visual acuity.



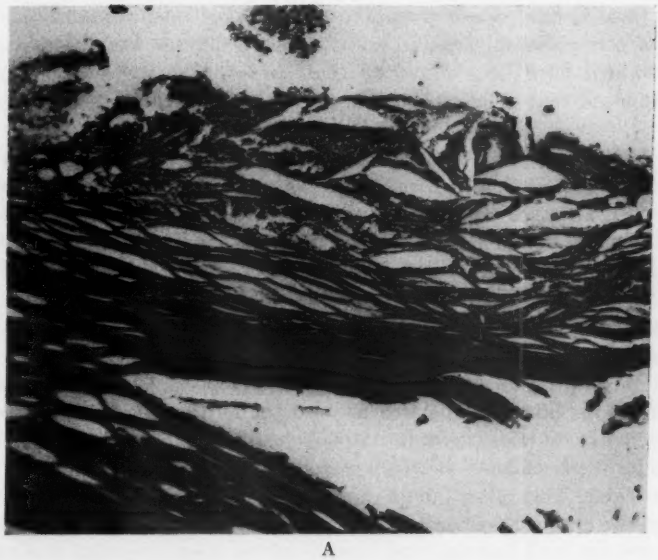
A



B

FIG. 4. Case 2: A. Specimens removed from left frontal region. The point of communication through the falx with the hematoma on the right side is not seen.

B. Roentgenograms of specimens removed in two stages. Two hematomas were present on the left, one on the right. Communication through the falx occurred at the upper (anterior) extremities.



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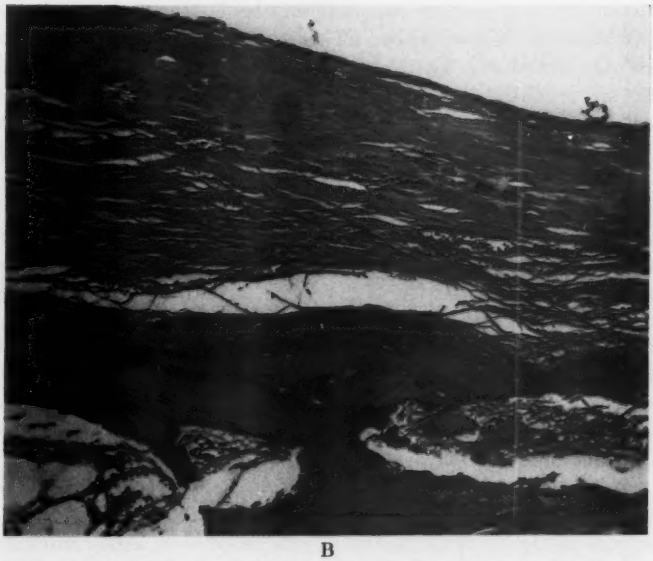

B

FIG. 5. Case 2: A. Photomicrograph of inner wall of right hematoma capsule. Debris is attached to the surface with necrotic cells. Cholesterol clefts are identified. Focal irregular areas of calcification were present throughout all sections but are not included in this area. × 160.

B. Bone formation with canaliculi, lamellae and a zone of osteoblasts. The bone surrounds an area which resembles fatty marrow but the cells cannot be identified definitely as hematopoietic elements. × 160.

As in Case 1, this patient presented with marked mental retardation and a history of convulsive seizures. In addition, she exhibited visual loss and optic atrophy which have been noted as common sequellae by previous authors. Speculation as to the cause of disturbance of the visual pathways will be brought out later.

Retardation of physical growth was a striking feature in this girl and during the few months following removal of the hematomas increased growth rate was apparent. Disturbance of growth usually is associated with lesions involving the parietal lobes of the brain whereas in this case the most severe compression seemed to be in the frontal area.

A particularly significant aspect of this case concerns the presence of true bone formation, in addition to amorphous calcification, noted in histologic sections from the right hematoma (figs. 5A & B). Griponissiotis[4] reported such a case in 1955 and was able to find only 4 previous reports. Chusid and Mahoney[1], in reviewing the literature, pointed out that the terms *ossified* and *calcified* have often been used interchangeably without justification. Ossification should be reserved for those instances in which osteoblasts and osteocytes in a bony matrix are identifiable. This raises the question of the mechanism of this development. Although the dura is the endosteum of the skull and is capable of bone formation it is usually assumed that this is a function of the outer layer and that the inner layer possesses no osteogenetic property. Moreover, it has been assumed that ossification occurs only in very long-standing hematomas while the patient reported by Chusid and Mahoney[1] had no history of injury prior to 2½ years before removal of the hematoma. In the present instance the clinical symptoms had their onset in definite relationship with the fall during infancy and one may conclude that the hematomas had been present for at least 6 years. It is believed that this represents the sixth verified subdural hematoma showing true bone formation and youngest reported so far.

A curious feature of the case was the communication through the falx between the hematomas associated with obliteration of the superior longitudinal sinus. A similar example has been seen in this clinic in an infant 1 year of age who presented with severe retardation of development and the appearance of microcephaly. Bilateral frontal subdural hematomas were demonstrated by contrast roentgenographic studies and at operation the hematoma was found to be a single fluid-filled sac crossing the midline with total absence of the falx in that region and obliteration of the superior sagittal sinus. The frequency of sinus occlusion in bilateral subdural hematomas and its role in the production of mental retardation must remain conjectural at present.

DISCUSSION

The clinical picture of the infant with subdural hematoma is extremely variable. In most instances there is no definite history of trauma as was elicited in both of the present cases. More often, birth trauma or some later head injury which seems insignificant to the parents, if at all recognized, may initiate the

bleeding. There also is increasing evidence that intrauterine trauma may tear the delicate vessels crossing the subdural space in the infant's malleable skull. At all events, the presenting symptoms usually are in the nature of drowsiness, irritability, or regurgitation or refusal of feedings rather than any specific neurologic deficit. Moreover, increased tension of the fontanelle is not consistently present. While certain infants show signs of increased intracranial pressure and may be mistaken for hydrocephalics, a similar number will present with small skulls and resemble microcephalics. This variable pathologic physiology encountered in the presence of similar lesions is not understood but it seems clear that in all instances of membrane formation there occurs some restriction of brain growth.

Davidoff and Dyke[2] have described the roentgenographic changes in the skull in "relapsing juvenile chronic subdural hematoma". These changes include: 1) Elevation of sphenoid wing, superior orbital plate and superior orbital ridge. 2) Deepening, widening, and lengthening of the middle fossa. 3) Disappearance or indistinctness of the oblique line delineating the posterolateral wall of the bony orbit. 4) Atrophy of the inferior and lateral wall of the superior orbital fissure. 5) Hypertrophy of the frontal and ethmoidal sinuses. 6) Thickening of the skull.

Of these changes none were present in the roentgenograms in Case 1 despite the fact that the lesions were known to have been present since infancy (fig. 1). It is apparent, therefore, that such changes are not constant and cannot be relied on to indicate the presence of a hematoma.

In Case 2 the roentgenograms contained many of the diagnostic features, so that a hematoma would have been suspected even in the absence of calcification (fig. 3). Thinning of the bone in the parietal regions, enlargement of the temporal fossa and loss of normal bony architecture about the sphenoid wings were, as pointed out by Davidoff and Dyke[2], related to the primary increased intracranial pressure exerted by the hematoma. The increased thickness of the cranial vault probably was secondary to the later decreased pressure and lack of brain growth.

In addition to the previously described roentgenographic changes there was a striking alteration in the shape of the skull which is believed to have resulted from localized restriction of growth in the frontal region. It must be recalled that skull growth is entirely dependent on the outward thrust from the enlarging brain. The restricted frontal expansion was indicated by the shallow anterior fossa and the compensatory increase in the width of the skull. Ingraham and Matson[5] noted that one of the features differentiating enlarged head due to subdural hematomas from that due to obstruction of the cerebrospinal fluid was that in the former the most marked increase was in the biparietal diameter while in the latter the increase was in the fronto-occipital axis. The present author is of the opinion that the increased biparietal diameter is secondary to restricted anteroposterior growth, the same as occurs in craniosynostosis involving the coronal sutures. Indeed, the configuration of the skull in this case resembled very closely that of premature closure of those sutures. It is significant that subdural hematomas in infancy are almost without exception of greatest thickness in the frontal

region and often are present only in that area. This is reflected clinically in the frequency with which mental retardation is seen rather than signs of motor or sensory disturbance.

The base of the skull also was involved in the abnormal configuration (fig. 3B). In craniosynostosis involving the coronal sutures visual disturbance frequently is seen as a late effect and has been attributed to kinking of the optic nerves at the optic foramen. It seems reasonable, therefore, that the same mechanism might be in operation in the presence of subdural hematomas which distort the floor of the skull.

There is still some disagreement as to the correct management of subdural hematomas in infancy. This disagreement concerns the necessity for removal of membranes around the hematoma after evacuation of the fluid contents. The present cases seem to indicate quite clearly the necessity for their removal. It is apparent from Case 1 that calcification is not necessary to render a membrane inelastic and restraining to normal brain growth for there was just as much growth disturbance on the side where no calcification occurred.

A second point in therapy is emphasized by Case 1. Removal of the membranes is not adequate treatment unless it is followed by repeated tapping of the subdural space until no further accumulation is found. If fluid is allowed to remain in that space new membranes will form and the pathologic process will repeat itself. In occasional instances, in which subdural fluid continues to accumulate despite frequent tapping, repeated craniotomies for membrane removal have been necessary.

SUMMARY

Calcification of a subdural hematoma is an uncommon finding in adults and is considerably more rare in the pediatric age group. Two cases of removal of such lesions from infants and children have been previously recorded and the present report adds 2 others to the literature. In one of these true bone formation was present, the youngest such case on record.

The symptomatology of chronic subdural accumulations in children is reviewed, emphasizing the frequency of mental retardation due to constriction and restraint of normal growth of the frontal lobes. The roentgenologic picture which results from this restriction of growth is clearly demonstrated in one of the patients. It is suggested that the mechanism of visual impairment which is a common late effect also is related to a change in shape of the calvarium and base of the skull.

The importance of complete evacuation of the subdural space and removal of the membranous capsule of hematomas to allow normal brain growth is again stressed.

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SUGGESTIONS ON TECHNIC IN THROUGH-AND-THROUGH WIRE CLOSURE OF ABDOMINAL WOUNDS

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The concept of primary through-and-through wire closure of abdominal wounds was developed and popularized in 1933 by Reid, Zinninger, and Merrell[3]. The merits of this closure are undeniable, and the authors have sought to modify certain details in technic so as to increase the applicability of this method and at the same time eliminate some obvious disadvantages.

Through-and-through wire closure has been advocated for special circumstances: 1. As a method of effecting rapid closure when the patient's condition demanded speedy termination of the operative procedure. 2. As a method of preventing evisceration when the possibility of wound disruption appeared abnormally high. The latter complication is often predictable in the face of serious contamination and potential wound infection; or where poor healing qualities exist, either because of malnutrition, age, or obesity; or where the occurrence of unusual stress by cough, ascites, or gastrointestinal distention is anticipated in the postoperative period. Since its proposal, the Department of Surgery at the Cincinnati General Hospital has continued with satisfaction to use this variety of closure for the circumstances described. Obviously, the patients for whom it was designed represent as an average a group of seriously ill and unusually poor operative risks.

Although we have been impressed with the virtues of the method, there has been a similar recognition of certain disadvantages:

1. This variety of closure is often painful in the postoperative period. If used as initially designed, i.e., without separate closure of the peritoneum and fascia, it is necessary to place the wires at reasonably close intervals of approximately 1¼ to 1½ inches apart and to twist the wires to reasonable snugness so that the intervening blocks of tissue accurately abut. Only in this fashion can one be certain that a loop of bowel or tag of omentum will not herniate between the wires, or that the tissue is approximated closely enough to heal properly. After 4 or 5 days, when agglutination of the opposing edges of the wound has taken place, it is possible to loosen the wires by untwisting them a full turn. This will often relieve some of the pain, but not entirely.

2. The wires tend to cut the skin. Despite the fact that the wire currently used is of large gauge, #20 or #22 gauge steel, it is still malleable, and pressure of the loop is often exerted on the skin at the site of the wire puncture, causing the wire to cut in this locale. Unquestionably a similar situation occurs underneath in the vicinity of the peritoneum.

3. Irrigation of the wound following closure with the wires, and in the face of heavy contamination of the soft tissue, is often difficult and leaves something to to be desired.

4. The most significant disadvantage of through-and-through wire closure, without complimentary closure of the peritoneum and fascia, is the frequent occurrence of postoperative hernia. This is understandable, since even in the most careful and experienced hands when the entire thickness of the wound edge is approximated, the layers of peritoneum and fascia may not be accurately opposed.

5. Reid, and associates originally advocated the use of silver wire. This was strong, malleable, and easily handled, both for insertion and twisting. During World War II, however, silver wire became difficult to obtain, and the quality of its tensile strength often fluctuated, so that a shift was made to stainless steel wire of #20 or #22 gauge. This is stronger than silver wire, but at the same time much more difficult to handle. If it is used on a large hand sewing needle it must be turned back and clamped down accurately where the loop is made with the eye of the needle, or else the loop exceeds the diameter of the needle and is very difficult to pull through the tissue. Moreover, the assistant must hold the wire taut at all times to prevent twists and kinks in the wire as it is placed. These difficulties have served in large measure to defeat one of the primary objectives for which the closure was designed, namely, a rapid closure; for when one encounters these minute details at the operating table with assistants and nurses who do not appreciate the necessity for exact compliance with these instructions, the closure often becomes prolonged and frustrating.

6. The hand sewing needle in itself is rather large since it must accommodate the wire. Besides often causing troublesome bleeding from puncture of vascular channels as it is inserted through the abdominal wall, it may provoke an occasional tear in the fascia in the region of its passage through which properitoneal fat or even omentum will herniate subsequently.

7. Down through the years, the through-and-through wire closure has often been modified for particular circumstances[1]. It has been recognized that this is the strongest closure which one can obtain against potential evisceration, so that it has often been used in conjunction with layer closure of the abdominal wall in patients wherein the factors of wound healing, stress and contamination are major concerns, and the factor of time relatively unimportant. In such situations, the wires have been used primarily as stays and have not been placed in as great number or as closely together. Such a closure is ideal as regards wound strength. but in the fashion in which it has been utilized, it has been both time consuming and tedious.

Recently, Hoxworth, and associates[2] introduced a new concept in the closure of abdominal fascia utilizing rigid wire sutures. Experimental and clinical observations demonstrated that such suture provided superior holding power over conventional suture material. Furthermore, it provided an exceedingly rapid method of abdominal wound closure. The authors emphasized, however, that this method is not to be misinterpreted as a substitute for through-and-through wire closure of abdominal wounds. The circumstances for which wire closure of the through-and-through variety is to be recommended remain the same. It is to be employed when it is necessary to close the abdomen with speed. It is like-

wise to be recommended in any situation where one encounters a patient in whom factors actively oppose prospects for good wound healing, i.e., where contamination has occurred, where wound infection may be anticipated, where conditions such as serious cough, intestinal distention are imminent, or where the patient is aged or nutritionally debilitated. In just such patients, where the need for through-and-through wire closure has obviously existed, the authors have sought to modify the technic of the closure in an attempt to preserve the security of the conventional through-and-through wire closure of the abdominal wall and to gain the advantage of approximating the abdominal fascia with rigid wire sutures, thereby eliminating many of the disadvantages which have been heretofore cited. No credit for originality is taken in any of the nuances to be described. Many of them have been mentioned and published before, and singularly, if not collectively applied.

METHOD. The through-and through # 20 gauge steel wire is passed through the abdominal wall very simply in the following manner: No needle is used; instead, the wire is cut obliquely with a wire cutter so as to sharpen the point of the wire. This may be done at the time of operation, or more conveniently the wires may be prepared beforehand and sanded to a fine point before autoclaving. In any case, the end of the wire must be cut sharply at an acute angle in order to enable easy passage through the skin. At the operating table the wire is grasped with a needle holder in the ordinary fashion about 1 to 1½ inches distal to the point, and by making traction on the peritoneum and fascia with Kocher clamps, the wire is easily passed through the full thickness of the abdominal wall. This eliminates the necessity for threading the wire on a needle and all the frustrations which commonly ensue when this combination is required. Having situated the wires as desired, the peritoneum and posterior fascia are now rapidly closed with a continuous suture of # 0 chromic catgut down to a point which will still admit entrance of the finger into the peritoneal cavity. At this junction, the finger is inserted into the orifice remaining in the peritoneal closure, and the wires are

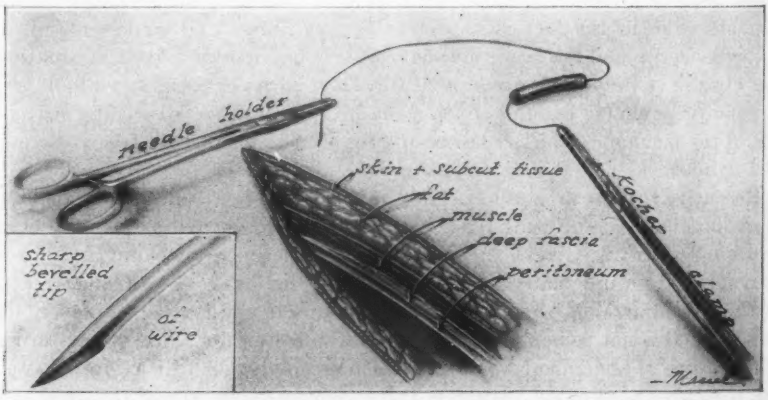

FIG. 1. The insert shows the manner in which the end of the wire is cut. The wire is grasped with the needle holder and passed through the thickness of the abdominal wall.

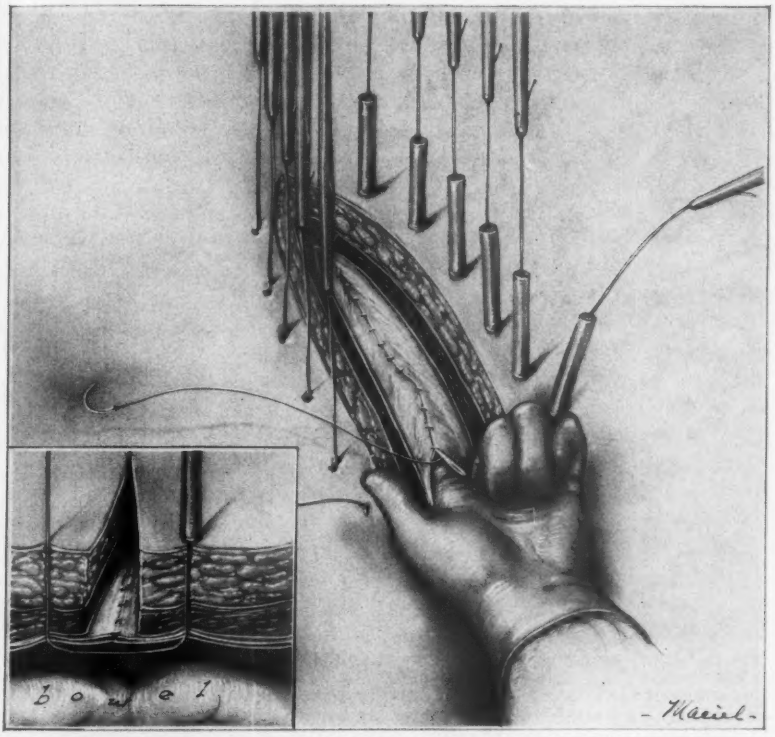

FIG. 2. The peritoneum has been closed down to a point which will admit a finger. The wires are now elevated into position under tension while the finger in the peritoneal cavity assures the operator that no bowel or omentum is incorporated between the sutures and abdominal wall.

drawn up vertically and taut. As they are individually elevated, the operator can pass the finger into the peritoneal cavity, feel the wire beneath the abdominal wall, and assure himself that no bowel or omentum is interposed between the loop and the anterior peritoneal surface. Two Kocher clamps are then placed on the wire at either side as it emerges from the skin so as to secure it taut and to lock the wire in the position which has been attained. The wires are treated successively in this fashion from one end of the wound to the other, and once they are all locked in the position designated, the remaining portion of the peritoneal closure is completed.

If one is faced with a peritoneal closure made difficult by poor relaxation, or by inability to approximate the peritoneum and posterior rectus sheath from whatever cause, the foregoing procedure can be modified. In such an instance, all of the individual wires should be pulled up taut and secured with clamps as they emerge from the abdominal wall, as previously cited. This should be done as the initial step in the wound closure, for by so doing, full advantage may be taken of

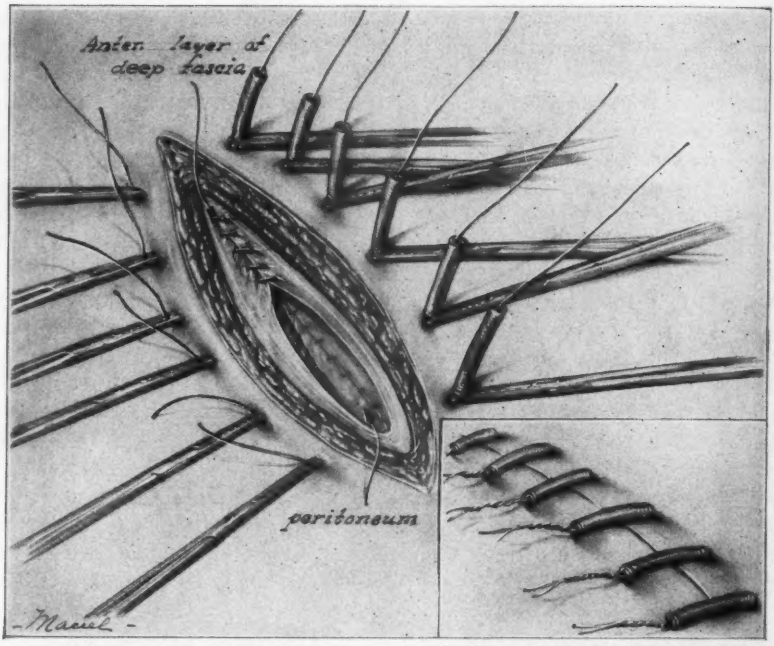

FIG. 3. Clamps are applied to the wires at points of emergence from the skin so as to lock the wires in the position indicated in figure 2. (The Kocher clamps at the ends of the wire are absent for illustration purposes.) The remaining defect in the peritoneum has been sutured. Hoxworth rigid wire sutures are being placed to approximate the fascia. The insert shows the through-and-through wires twisted down into final position.

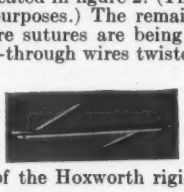

FIG. 4. Magnified illustration of the Hoxworth rigid wire suture which is used to approximate the fascia.

the tensile strength of the wires to approximate the entire thickness of the wound. The peritoneum and posterior rectus sheath can then be sutured in conventional manner without the hazard of having the peritoneum tear or pull apart.

Once the peritoneal suture has been accomplished, the wound can be irrigated without interference by the wires. The fascia is then rapidly closed with interrupted rigid wire sutures, as advocated by Hoxworth, and associates[2]. The rigid wire sutures not only afford superior holding power to conventional sutures, but afford several distinct advantages in this situation:

1. They are inert in so far as tissue reaction is concerned and thus eliminate foreign body reaction and the tendency to wound infection where contamination has occurred.

2. They supply strong, accurate apposition of the fascia.

3. They can be inserted rapidly within the space of 2 to 3 minutes in even long, vertical or transverse incisions.

Following the suture of the fascia, the through-and-through wires are then twisted down into position in the conventional manner. Since they now serve mainly as stays to augment the power of the layer closure, they need not be tied down as tightly as when the wire constitutes the only means of apposition. This greatly eliminates the postoperative pain usually seen with through-and-through wires, and the cutting of the skin which is so frequently observed. If the patient's postoperative course is good and without complication, the wires can be removed in 12 to 14 days on an average or when the wound healing and proper tensile tensile strength has been reached in the judgment of the surgeon. On the other hand, if complications ensue and the patient's condition remains critical or desperate, the wires are in place to guard against evisceration and may be left in for longer periods of time.

COMMENT

The authors believe that the closure just elaborated has many points of merit:

1. It is the strongest closure which the surgeon can presently provide.
2. It can be performed in the manner described with relative rapidity.
3. It provides for exact approximation of the individual layers.
4. Suture material which provokes foreign body reaction has been minimized.
5. The strength of the closure allows mobility and ambulation in patients who might otherwise have been greatly restricted because of the surgeon's concern about a less secure wound approximation.
6. It has provided significant economy by allowing earlier dismissal from the hospital. With the wire stay sutures in place, one can allow discharge in a patient who might otherwise have had to remain hospitalized awaiting the natural increase in wound strength. The wires are removed subsequently in the office.

SUMMARY

Some modifications on the use of through-and-through wire closure have been suggested. It is believed that these modifications retain the advantages of wire closure as originally suggested by Reid, Zinninger, and Merrell, i.e., to provide a rapid closure of the abdominal wall and to prevent evisceration. In addition, the ability to individually approximate the constituent layers eliminates the high incidence of postoperative hernia and many of the technical details which have been disturbing heretofore.

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MAJOR VASCULAR INJURIES INCIDENT TO INTERVERTEBRAL DISK SURGERY

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The purpose of this paper is to call attention to the danger of serious vascular damage incident to surgery of intervertebral disk. The general surgeon, as well as the orthopedic and neurosurgeon, should be aware of the danger of this complication since, although he may never actually perform disk surgery, he may well be called upon to treat an injury to a major vessel, which can and does occur even in the hands of the most experienced and skillful operator.

CASE REPORTS

Case #1: M. B., a white woman, aged 69, was admitted to the hospital in June 1952 with a history of back pain of several years' duration. A myelogram 2 days after admission confirmed the diagnosis of a herniated disk at L 4 and 5. The following day a laminectomy was performed with removal of the fourth lumbar disk. The operative note mentions a large varicosity at L 5 and S 1, but there was no unusual bleeding, no sign of clinical shock and no known perforation of the anterior ligaments of the spine. The patient was discharged on the eleventh postoperative day with no knowledge at that time that anything unusual had occurred.

Three and one-half weeks after the laminectomy the patient noticed swelling of her ankles and abdomen, with some shortness of breath. She was seen at home by her family doctor and immediately sent back into the hospital. At that time she was in marked congestive failure, as evidenced by all the unusual clinical signs, namely dyspnea, moist rales throughout both lung fields, pitting edema bilaterally, a very large and moderately tender liver and pronounced cardiac enlargement. (See roentgenogram of chest, fig. 1 A.) In addition, she presented about as loud a bruit and pronounced a thrill as one is likely to encounter. The thrill could easily be felt throughout the abdomen and back, and the bruit was clearly heard over the entire trunk. It was obvious that this represented an arteriovenous communication, and it was clear from the rapid onset and development of the congestive cardiac failure and from the magnitude of the bruit and thrill that large vessels were involved. The very intensity of these valuable clinical signs (bruit and thrill) made it somewhat difficult to localize the point of maximum intensity and thereby determine the exact location of the fistula, but it was concluded that this was in the region of the bifurcation of the aorta or the common iliac vessels. A study of the anatomy of this region showed these vessels to be in a vulnerable position in relation to the site of the previous operation. The patient was treated for congestive failure, and 1 week after admission, or 6 weeks postlaminectomy, an aortogram helped to confirm the diagnosis and establish the near vicinity, if not the exact location, of the fistula. (See figs. 2 and 3.)

Operative procedure (fig. 4): The operation for the arteriovenous aneurysm was performed 7 weeks after the original procedure and 2 weeks after the second admission. The fistula was identified as a communication between the right common iliac artery and the lower end of the vena cava where the artery crosses the vein (fig. 5). There was still, after 7 weeks, some residual of the extravasated blood and considerable inflammatory reaction. Various methods for obliteration of this fistula were considered with the idea in mind of trying to reestablish continuity of both vessels. However, it was thought safest and best to be satisfied with ligation and division of the artery just above and just below the fistulous

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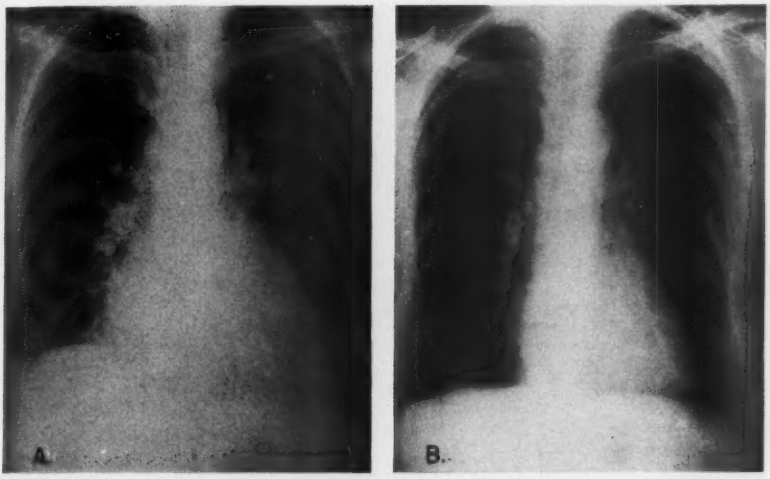

FIG. 1. Case #1, M. B. (A). Preoperative roentgenogram of chest showing cardiac enlargement, pulmonary congestion and some fluid at the right base. (B). Postoperative roentgenogram of chest showing clearing of the signs of congestive failure.

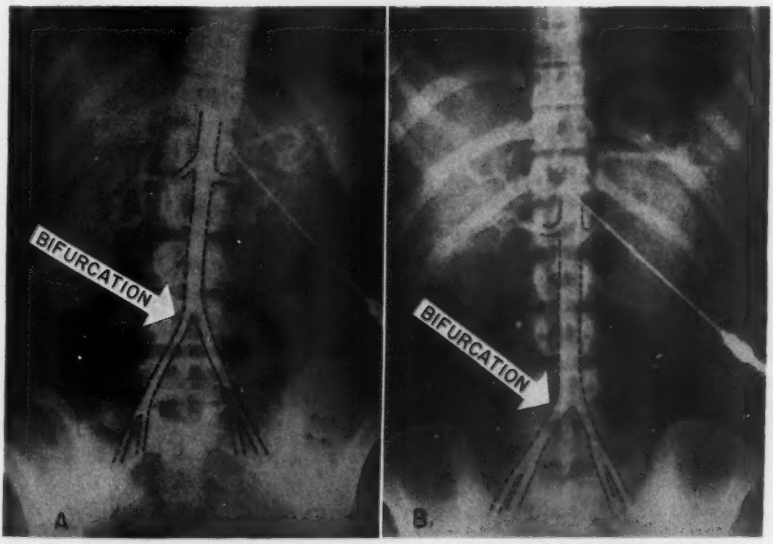

FIG. 2. Aortograms, normal, for purpose of this discussion. Dotted lines indicate the margins of the vessels. These pictures clearly demonstrate the relationship of the aorta and the common iliac arteries to the bodies of the lumbar vertebrae and to the intervertebral spaces. One also can see from these aortograms that there is appreciable variation in the location of the aortic bifurcation.

FIG. 3. Case #1, M. B. Aortogram. Dotted lines indicate the margins of the vessels. This film was taken immediately after the dye had been injected. The aorta itself has emptied immediately while the renal arteries and the iliac arteries are still filled. At the same time the vena cava is completely filled with dye from its lowermost extremity well up towards the diaphragm, and is very much larger than normal.

opening, leaving the small segment of artery attached to the vena cava. Immediately after the close of the operation a continuous caudal block was established and utilized for several days. The evening of the same day very faint but definite pulsations were palpable in the right dorsalis pedis arteries, for the first time on this admission. This patient has now been followed for over 3½ years and there is no evidence of vascular insufficiency in the right leg resulting from the operation. The congestive failure cleared rapidly, (fig. 1 B) and she leads a normally active life for a woman of 72 years.

The above is the only 1 of the 4 cases in which the author was personally involved (as surgical consultant for the arteriovenous aneurysm). The following 3 cases are reported with the kind permission and friendly assistance of colleagues in the Cincinnati area.

Case #2: J. M., a white man, aged 44, was admitted to the hospital in May 1952, with a diagnosis of herniated intervertebral disk at L 4 and 5 on the right. The diagnosis was well substantiated by history, examination and myelogram. On May 8 a laminectomy was performed with removal of the fourth lumbar disk. Toward the termination of the procedure of evacuating remnants of degenerated nucleus pulposis, and while the operator was in the process of explaining to his assistants the reasons for extra care in this region, there was a sudden gush of arterial blood into the field—approximately 50 to 75 cc. This was promptly controlled by a pledge of oxycel cotton and a few seconds later, when the cotton was removed, no further bleeding occurred. There was a slight fall in blood pressure and 1 unit of blood was administered. The patient was watched very carefully during the postoperative period with full awareness of the danger of a vascular complication. However, it was not until late in the afternoon that the patient began to complain of pain in the left flank and was noted to be developing some abdominal distension. This was followed by falling blood

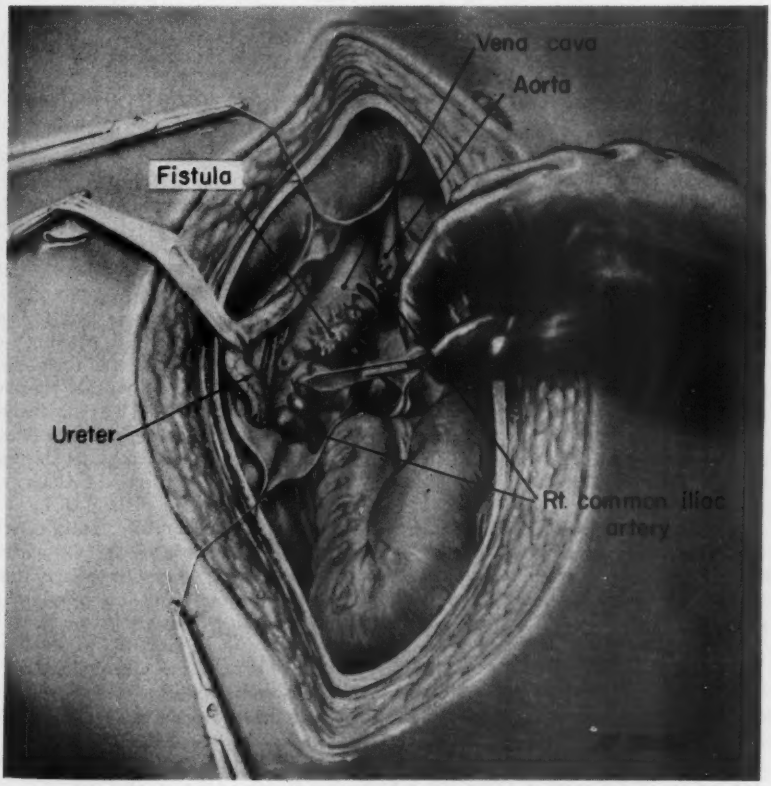

FIG. 4. Case #1, M. B. Drawing of operative procedure

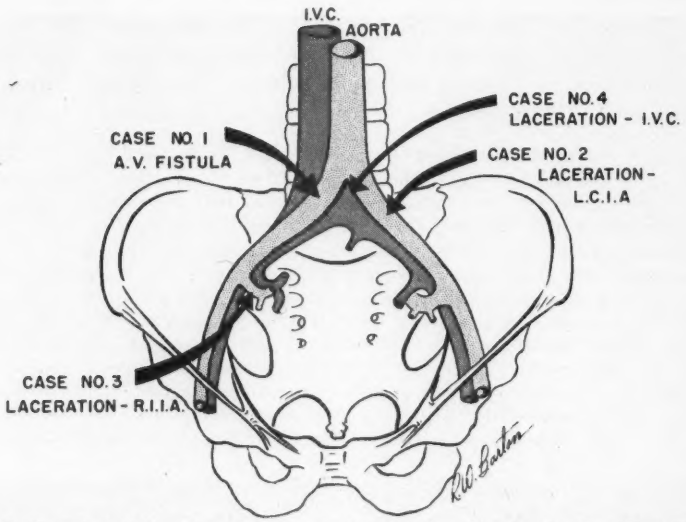

FIG. 5. Anteroposterior view of anatomy of the region also showing location of injury in cases 1, 2, 3 and 4.

pressure and rising pulse, and a prompt diagnosis of impending shock from blood loss. Eleven hours after the initial procedure had ended the abdomen was opened, disclosing a large retroperitoneal hemorrhage on the left side, coming from a lacteration of the left common iliac artery (fig. 5). The hemorrhage was readily arrested by ligation of this artery. The patient was discharged from the hospital on the nineteenth postoperative day, after a very satisfactory course, and no signs of circulatory insufficiency in the left leg or foot other than absent pulsations. He has been followed carefully since then, and there are still no signs of impaired circulation.

Case #3: R. F., a white man, aged 51, was admitted to the hospital on June 24, 1952 with history and findings of a herniated intervertebral disk at L 5 and S 1, confirmed by myelography. The following morning, starting at 8 o'clock, he was operated upon. By 9 o'clock the fifth lumbar disk had been removed and there had been no unusual bleeding. However, between 9 o'clock and 9:10 his blood pressure began to drop and his pulse became weak end rapid. At 9:10 blood was started under pressure, and by 9:30 the skin was closed. The patient was turned onto his back and a second unit of blood was started. At this time the operating team thought that the patient probably was suffering from a coronary occlusion. However, it was soon noted that his abdomen was becoming distended. For this reason a needle was introduced intraperitoneally and blood withdrawn. Intra-arterial transfusions were started in both radial arteries and the abdomen was rapidly opened. Huge quantities of blood were found within the abdominal cavity, coming from a transverse laceration in the right internal iliac artery, directly opposite a tear in the anterior vertebral ligament (fig. 5). The bleeding was controlled with Potts clamps, but at that moment the patient went into a state of cardiac arrest. Thoracotomy was done promptly with massage of the heart, but the only cardiac action that could be obtained was a rapid ventricular fibrillation. The defibrillator was used repeatedly, but it was impossible to restore normal cardiac rhythm, and the patient died at 12:05. This probably was about 3 hours after the vascular injury had occurred.

Case #4: E. S., a white man, aged 59, was admitted to the hospital with a characteristic 5 year history, and physical findings substantiating a diagnosis of herniated intervertebral

disk. Myelograms performed at the time of admission revealed defects in the spinal canal on the right side at the level of L 4 and 5, and on the left side at the level of L 5 and S 1. A bilateral laminectomy was performed with removal of degenerated intervertebral disk fragments. During the course of the operative procedure a gradual drop in blood pressure was noted, and 2 pints of blood were administered while the operation was in progress. At the termination of the procedure, the patient was removed to the recovery room for observation. For several hours the blood pressure remained at relatively low levels and the pulse rapid, and the patient was given several liters of saline solution and an additional 2 pints of blood intravenously. Despite the intravenous therapy the patient failed to respond. Nine hours after the beginning of the operative intervention the blood pressure suddenly fell to zero, the pulse became unobtainable, and the patient died. Postmortem examination revealed a moderate amount of partially clotted blood in the peritoneal cavity and a huge retroperitoneal hematoma extending from the diaphragm to the pubic region completely engulfing all retroperitoneal structures in the area. Upon evacuation of the hematoma a perforating defect was noted on the ventral surface of the intervertebral space between L 4 and L 5 and a V shaped defect was present on the left side of the inferior vena cava at point of closest contact to the space between L 4 and L 5 (fig. 5). The defect measured 0.5 cm. at its widest point. The remainder of the autopsy examination was unremarkable.

These 4 cases, managed by completely different teams in 4 different hospitals in the Cincinnati area, demonstrate a number of interesting points, but of first importance is the following:

The one patient in whom the operator was aware of the danger of this complication, and recognized its occurrence, was promptly and successfully treated by ligation of the left common iliac artery. Of the 3 patients in whom the operator was not aware of this danger and the injury was not recognized, 2 died of massive hemorrhage and 1 rapidly developed a large and disabling arteriovenous fistula.

Figures 5, 6 and 7 demonstrate the close relationship between the major vessels and the anterior surface of the vertebral bodies and the intervertebral spaces. There is a certain amount of variability in the anatomy of this region as seen in the aortograms. It should be noted that these vessels are in a fixed position and cannot be pushed out of the way of the offending instrument, as might happen in other parts of the body.

The importance and value of well documented and carefully studied case reports could hardly be more dramatically emphasized than by the situation which presented itself in the handling of Case # 1. When the family physician saw this patient at home in severe congestive failure and requested medical consultation, and he in turn, after careful study, requested surgical consultation, no one in the group, including the family physician, orthopedic surgeon, medical consultant or surgical consultant, had ever encountered an exactly similar situation, nor was any one of them aware of how readily and frequently serious vascular damage can occur during the course of disk surgery. The surgical consultant naturally searched the general surgical literature, and found the case reported by Linton and White[4] in 1945 under the reassuring title "Arteriovenous Fistula Between the Right Common Iliac Artery and the Inferior Vena Cava—Report of a Case of Its Occurrence Following an Operation for a Ruptured Intervertebral Disk with Cure by Operation." The authors not only reported in detail on their own carefully studied case, which except for the time

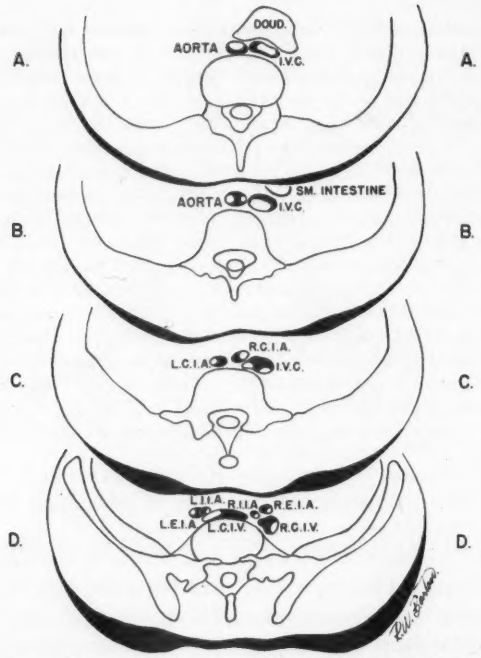

FIG. 6. (A). Cross section at level of third intervertebral disk. Here the vulnerable structures are the aorta, the vena cava and the third portion of the duodenum. (B). Cross section at level of the lower portion of the fourth lumbar vertebral body, showing the proximity of the aorta, the vena cava and the small bowel. (C). Cross section at the upper edge of the fifth lumbar vertebra, or very close to the L4–5 intervertebral space. Here one can readily see how an instrument plunging through the anterior fibrous ligament of the spine can injure the vena cava and the right common iliac artery, producing the arteriovenous aneurysm which was seen in Case #1, or can lacerate the left common iliac artery as in Case #2, or the vena cava as in Case #4. (D). Cross section at the lower edge ofthe fifth lumbar vertebra or close to the L-5 S-1 intervertebral space. Here one sees how the right internal iliac artery can be injured as in Case #3. (Modified from: Eycleshymer, Albert C. and Schoemaker, Daniel M., A Cross-Section Anatomy. Courtesy of Appleton-Century-Crofts, Inc.)

element, almost duplicated the picture of the patient in question, but, on the basis of their extensive experience, discussed the reasons why such injuries can occur, the collateral circulation, and the various methods of handling arteriovenous fistula in general. In addition, they demonstrated two points of very practical importance relevant to the particular problem: 1. That the common iliac artery can be ligated with relative freedom from danger of severe ischemia or gangrene of the extremity, because of the extensive collateral circulation. 2. That the fistula can be managed by dividing and ligating the common iliac artery above and below the communication leaving the small segment of artery attached to the vena cava, because of the absence of branches in this portion of the artery.

The case reported by Linton and White[4] in a general surgical journal, and

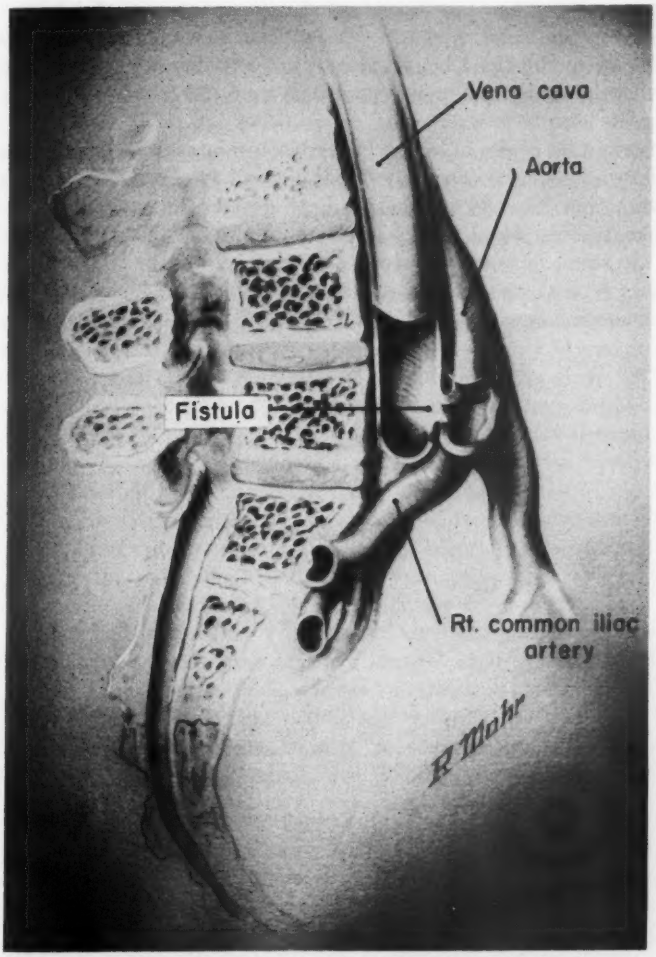

FIG. 7. Case #1, M. B. Drawing showing fistula—lateral view. This drawing was originally made to show the location of the fistula in Case #1, but it also is a good lateral view of this region, again demonstrating the close relationship between these major vessels and the anterior ligaments of the spine.

one reported by Holscher[3] in an orthopedic journal, were the only 2 cases found after careful and thorough search at the time that the first 3 patients sustained vascular injury incident to disk[3] surgery in the Cincinnati area (1952). Since then only 4 more cases have been added to the literature, making a total of 6 individually reported. Harbison,[2] who reports 1 of the 6, also sent a question naire to a large group of surgeons throughout the country and was able to gather information on 25 additional cases which had never been put into the

literature, making a total of 31 patients* with serious vascular injury and 1 with injury to the small intestine. The 4 cases documented herein bring the total to 36 (including the 1 bowel injury), but as pointed out by Harbison and others,[2] there probably are many more that were either not recognized or not reported.

The distribution of site of injury in Harbison's[2] interesting group of collected cases is shown in figure 8. The importance of the awareness of the danger of this complication and its early recognition is clearly demonstrated by an analysis of Harbison's series. The 1 case of intestinal injury was recognized immediately because intestinal mucosa was seen in the bite of the pituitary forceps. The patient was promptly treated by resection of the injured segment of bowel and primary anastomosis with a good result. Of the 30 patients with serious vascular

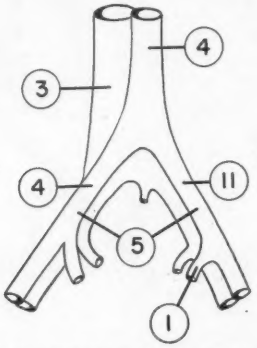

FIG. 8. Distribution of cases in Harbison's series. By far the largest number of injuries involved the common iliac arteries. Six of these 30 patients developed arteriovenous aneurysms. (From: Harbison, Samuel P., Major Vascular Complications of Intervertebral Disc Surgery. Courtesy of J. B. Lippincott Co.).

damage 17 died, giving an over-all mortality rate of 61 per cent. Approximately one-third of the patients were treated immediately and two-thirds were not. As one might expect, the mortality rate is appreciably lower in those who did have the benefit of immediate therapy—44 per cent as against 68 per cent. Probably the most important and interesting observation to be drawn from this series of cases is that in only 18 per cent of the patients was the injury manifested by excessive bleeding during the laminectomy. In the other 82 per cent, at the close of the procedure it was not known that serious vascular damage had occurred. There is an obvious discrepancy between the 18 per cent recognized by excessive bleeding and the 33 per cent who received immediate treatment. The other 15 per cent of the one-third who were treated promptly were diagnosed not by excessive bleeding at the time of surgery, but by careful observation of the clinical signs of blood loss, and a high index of suspicion.

The individual case which was managed and reported by Harbison[2] was that of an arteriovenous fistula between the left common iliac artery and vein, suc-

* One of the 31 appeared in the literature too late to be included by Harbison.

cessfully handled by division of the fistula and restoration of the continuity of the artery and vein.

In the case reported by Holscher[3] in 1948, "a very able and well-trained surgeon . . . was making a distinct effort to prevent such an incident—when . . . with surprising ease . . . the pituitary rongeur (closed) slipped through the interspace . . . as the instrument was withdrawn, a copious welling up of dark blood immediately occurred in the joint." The patient developed an arteriovenous fistula between the right common iliac artery and vein, successfully treated 6 months later by ligation of artery and vein above and below the communication.

Seeley, and associates,[5] reported 2 cases in 1954 as follows: #1, a 3 mm. longitudinal laceration of the left common iliac artery manifesting itself by a state of shock, and successfully repaired by interrupted everting mattress sutures of fine arterial silk, thus reestablishing the continuity of the artery; #2, a laceration of the right common iliac artery leading to a huge false aneurysm, repaired by the use of an arterial graft, followed by secondary hemorrhage and by a secondary operation, with ligation of the artery and vein proximal and distal to the bleeding point in the graft.

Glass and Ilgenfritz[1] apparently had an experience somewhat similar to our own (Case #1) as late as June of 1953. They report a case of arteriovenous fistula between the right common iliac artery and the vena cava manifesting itself immediately after laminectomy for a disk at L 4 and 5. This case was successfully handled by quadruple ligation and excision. These authors comment upon the similarity between their case and that reported by Linton and White[4] in 1945, and upon the absence of similar cases recorded in the surgical literature. They do, however, point out that arteriovenous fistula has been reported as a complication of numerous other surgical procedures such as hysterectomy, nephrectomy, thyroidectomy, introduction of Steniman pins for skeletal traction, application of Roger Anderson splints and thoracentesis.

Analysis of the 4 cases reported herein and the 6 individually recorded in the surgical literature brings out certain features which are sufficiently important to deserve additional comment.

Ten Cases of Vascular Injury

5 lacerations of individual vessels

4 involved common iliac artery (2 right, 2 left)
1 involved vena cava

Treatment and Results

1 repaired by primary suture restoring continuity of artery
1 ligated primarily
1 managed by use of arterial homograft, but after secondary hemorrhage ligation was required
2 died of massive hemorrhage

5 developed arteriovenous aneurysm

3 involved right common iliac artery and vena cava
2 involved common iliac artery and corresponding vein (1 right, 1 left)

Treatment and Results

2 had ligation of artery above and below fistula, leaving segment of artery attached to vein
1 had quadruple ligation
1 had quadruple ligation and excision
1 had division of fistulous tract and reestablishment of continuity

In 3 cases the operator is known to have been aware of the danger of this complication, and in 2 he was actually discussing the matter when the accident occurred. This would indicate that knowledge of this serious problem is not enough to assure avoidance of the complication although such knowledge does make its recognition and early treatment much more likely.

Bleeding worthy of being noted in the operative record occurred in 4 patients, and in all was easily controlled by the use of Oxycel, Gelfoam or plain packing. It should be noted that this can give a false sense of security and should not prevent the most careful observation during the postoperative period.

Severe shock occurred during the operative procedure in the 2 patients who died of massive hemorrhage. Shock developed gradually during the operative and postoperative period in 1 patient. It was encountered immediately after turning the patient from prone to supine position in 2, and within a very short time after turning, in 1. This sudden development of shock following a change of position indicates that pressure on the abdomen, which seems to be difficult to avoid in spite of efforts in that direction, does two things: 1. It presses the vessels and even the intestine back against the anterior ligaments of the spine, thus making them even more vulnerable than they would otherwise be. 2. This position masks the injury because the pressure temporarily tends to control the bleeding.

SUMMARY

Four cases of major vascular damage incident to disk surgery, occurring in four different hospitals in the Cincinnati area, are recorded. The literature is reviewed, including 6 individually recorded cases, and a group of 30 collected by Harbison by means of a questionnaire.

CONCLUSIONS

Major vessel injury is an ever present hazard in surgery of the intervertebral disk and can occur in the hands of the most competent and careful operators.

It is usually not manifested by excessive bleeding, and so must be recognized by careful clinical evaluation of the postoperative state and awareness of the danger of this complication.

Prompt recognition and treatment is the only method of reducing the disastrous mortality rate. The method of treatment may vary according to the site and extent of injury.

Restoration of the continuity of the injured vessels by suture or arterial graft may at times be desirable but is by no means always essential; ligation along may in some instances be simpler and safer.

The common iliac artery, which is the most frequent site of injury, can be ligated with relative impunity because of its extensive collateral circulation.

An arteriovenous aneurysm involving the common iliac artery can be treated by ligation of the artery above and below the fistula, leaving the small segment of artery attached to the vein because of the absence of branches in this portion of the artery.

Sympathectomy at the time has been advocated (White and Linton) and should be considered, but is certainly not essential for preservation of the viability of the extremity.

The prone position of the patient on the operating table with anteflexion of the spine, compresses the major vessels against the spine, thus putting them in an extremely vulnerable position and masking the injury when it does occur.

The pituitary forceps is the instrument most commonly responsible for vascular damage.

Awareness of this danger, although extremely important, is no assurance that the injury will not occur.

The ease with which bleeding is controlled by means of Gelfoam or Oxycel is not a safe criterion as to the extent of the injury.

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COMBINED NERVE AND TENDON INJURIES IN THE HAND AND FOREARM*

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Combined nerve and tendon injury in the hand and forearm imposes a serious economic handicap to the working man or woman and too often influences the future life of children. All surgeons who have assumed the responsibility for the care of the patient with such an injury know that complete recovery does not always occur; nevertheless, under proper circumstances many patients obtain a gratifying functional result.

Accidents involving the hand occur at any hour and not infrequently the patient confronts the physician or surgeon when strain and stress are greatest. First-aid care is an important, pertinent and vital factor in the management of such injuries. We, in agreement with others,[3] advocate covering the wound immediately with a layer of sterile gauze dressings or other clean cloth. Gauze bandage applied firmly over this usually will control both arterial and venous bleeding. Elevation of the extremity will reduce blood flow to the distal parts. Rarely is a tourniquet around the arm or forearm needed to control hemorrhage. In addition, these simple first-aid principles applied at home will quiet the apprehensive, nervous members of the family or at the hospital serve to keep method and order among the medical personnel. The control of hemorrhage as stated cannot be minimized and decidedly affects the succession of events which follow.

Correct definitive treatment of combined nerve and tendon injury, immediate or delayed, is dependent upon an accurate diagnosis. The significant data pertaining to the injury should be noted including time of injury, the nature, mechanism and instrument of violence, condition of the external wound and surrounding parts, and any abnormal objective or subjective changes observed in the involved extremity.

After a general survey of the patient a careful detailed examination of the injured hand is made. Without removing the first-aid compression dressing the surgeon should recognize with certainty the division of nerves and tendons and identify the injured and the intact structures. This may tax his diagnostic skill. Regional anatomic and neurologic knowledge are not only important but imperative to establish accurate diagnosis.[2]

Diagnosis of nerve and tendon injury in the hand is a complicated and, frequently, an impossible task if the patient is uncooperative. In our clinic alcoholism has been the chief obstacle in the establishment of a correct diagnosis. With extreme alcoholic intoxication the patient is not a candidate for detailed examination nor a good surgical risk. Under such circumstances delayed definitive treatment is the procedure of choice. Young children present a difficult problem

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and since the surgeon cannot make an accurate diagnosis in this group, a wise approach to the problem is definitive exploration of the wound in the operating room under general anesthesia.

Too frequently, the damage found at operation surpasses that expected by the surgeon. Damage to blood vessels with large expanding hematomas may limit function by reason of ischemia. Divided tendons and laceration of muscles inhibit normal movement and simulate nerve paralysis. If a bone has been fractured, pain may limit motion and lead to an erroneous impression. Spasm of arteries from various injuries may interfere with motion and further confuse the exact diagnosis.

ANATOMIC CONSIDERATIONS

Anatomically speaking, the hand includes all structures from the distal end of the ulna and radius to the terminal phalanges of the fingers. Peripheral nerve injury of this region is concerned with two of the three major nerves of the upper extremity; namely, the ulnar and median nerves. At the wrist the radial nerve is represented by its terminal superficial sensory branch, and seldom is exposed for repair.

The *median nerve* is most frequently injured at the wrist for two reasons: first, the volar aspect of the wrist is a frequent site for laceration, and second, the median nerve is at its most superficial position. From the diagrammatic drawing (fig. 1) one will note that diagnosis of median nerve injury in the hand is based upon two simple tests: first, the median motor function of the thumb, and second, sensory disturbance in the absolute area of median nerve innervation. Both are positive if the median nerve is divided from a level at the point of division of the lateral and median portions or proximal to it. Depending upon the site of injury, either motor or sensory disturbance may be demonstrated if severance occurs distal to this palmar division.

Digital adduction of the thumb is the only motor test which will demonstrate the integrity of the nerve distal to the transverse carpal ligament. The opponens pollicus flexes the first metacarpal bone, drawing it mediad over the palm of the hand, and the flexor pollicus brevis flexes and adducts the proximal phalanx of the thumb. The palmar surface of its distal phalanx comes in contact with the palmar surface of the other digits. This action is based upon the movement of the opponens pollicus which is innervated only by the median nerve.

Palmar abduction of the thumb is due chiefly to action of the abductor pollicus brevis which is innervated by the median nerve and the flexor pollicus brevis which is innervated by the median and ulnar nerves or by the ulnar nerve alone. The abductor pollicus brevis draws the thumb forward in a plane at right angles to that of the palm of the hand. Stabilization in this position also is dependent upon action of the flexor pollicus brevis, the abductor pollicus longus, and the oppenens pollicus. This action is a combined motor function of median and ulnar nerves, but may be used as a test of median nerve function when the ulnar nerve is not damaged.

Interruption of median nerve function can be confirmed by sensory examina-

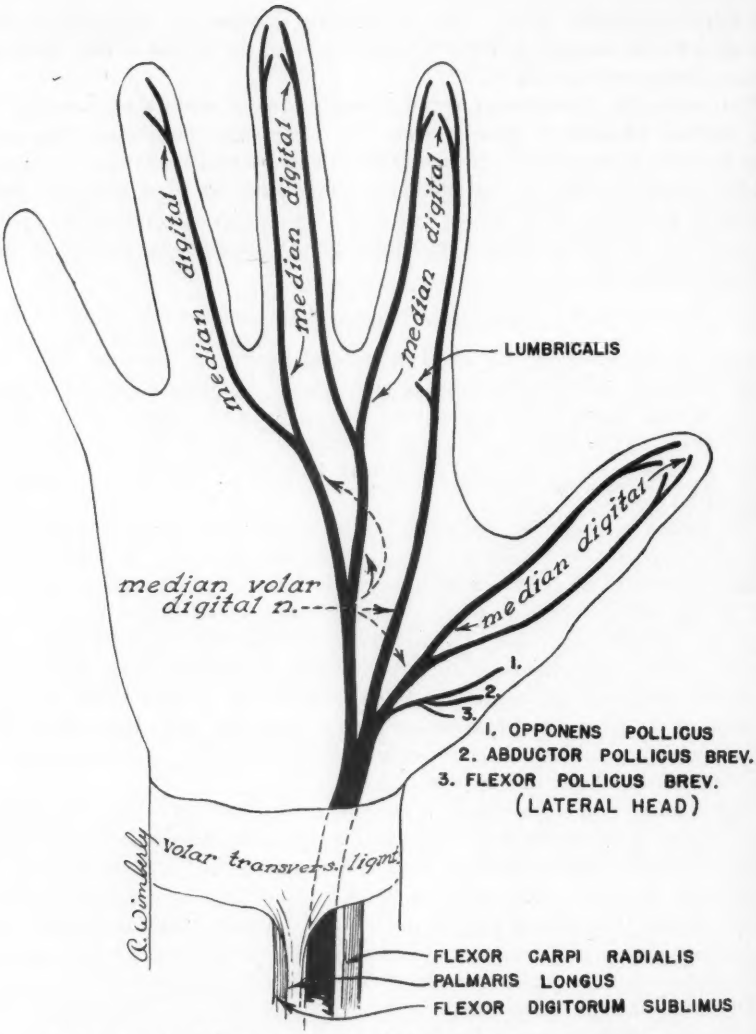

FIG. 1. Drawing showing the anatomic distribution of the median nerve

tion. Complete anesthesia over the dorsal area of the distal phalanx of the index finger indicates median nerve disruption.

The anatomy of the *ulnar nerve* is shown in the diagrammatic drawing (fig. 2). Approximately 5 cm. above the wrist the large dorsal cutaneous branch of the ulnar nerve originates and may be mistaken for the parent trunk. This branch passes dorsad along the flexor carpii ulnaris muscle and perforates the deep fascia. It then runs along the ulnar side of the back of the wrist and hand,

dividing into two dorsal branches: one supplies the ulnar side of the little finger and the other, the adjacent sides of the little and ring fingers. Other branches communicate with the superficial sensory branches of the radial nerve. The volar branch or parent trunk crosses the transverse carpal ligament on the radial side of the pisiform bone and ends by dividing into a superficial and deep branch.

The superficial branch supplies the palmaris brevis and the skin of the ulnar

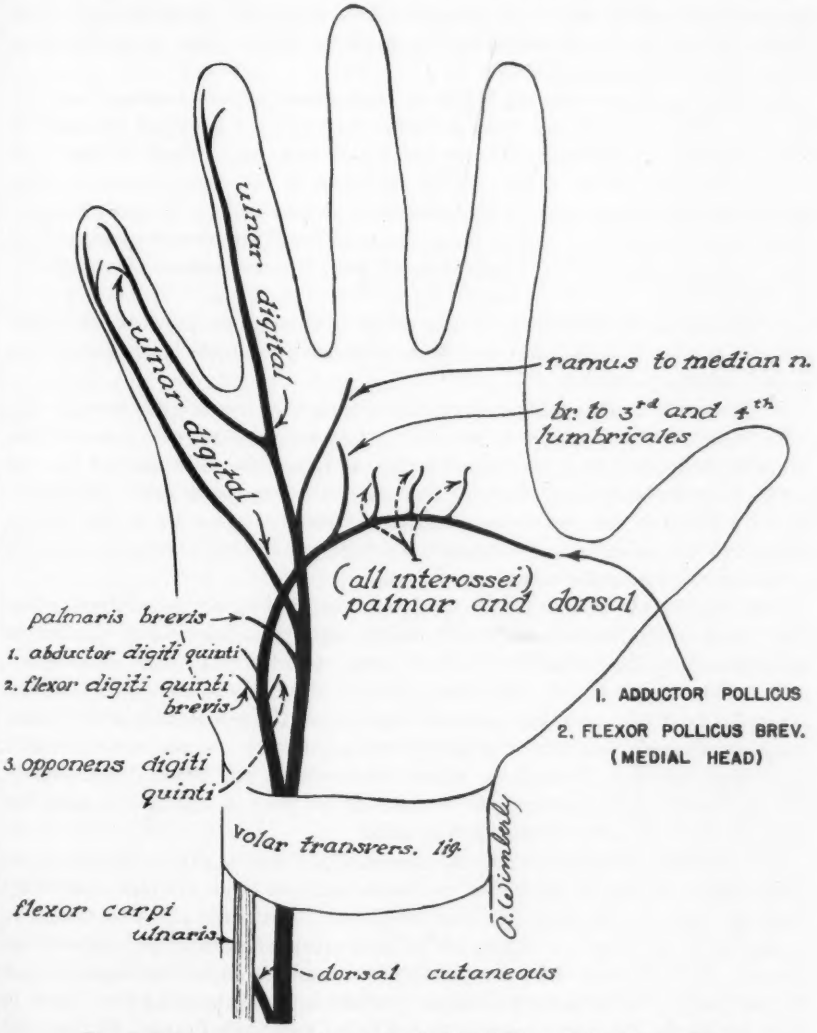

FIG. 2. Drawing showing the anatomic distribution of the ulnar nerve

side of the palm. It divides into a proper volar digital branch for the ulnar side of the little finger and in a common volar digital branch. These become the digital nerves for the adjoining sides of the little and ring fingers. The common volar branch also sends a communicating twig to the median nerve.

The deep branch is accompanied by the deep branch of the ulnar artery passing between the abductor and flexor of the little finger. It perforates the opponens of the little finger and follows the deep arch dorsal to the flexor tendons in the hand. It supplies these three short muscles of the little finger. As it crosses the deep part of the hand it supplies all of the interossei, the third and fourth lumbricales, and ends by supplying the adductor pollicus and the medial head of the flexor pollicus brevis.

The terminal ulnar nerve distribution in the hand permits accurate diagnosis by both motor and sensory tests provided the examiner does not misinterpret anatomic facts. Specifically, if only the dorsal cutaneous branch of the ulnar nerve is divided at the wrist, only sensory loss of the dorsal cutaneous area can be elicited. Conversely, if the parent nerve trunk alone is severed, motor disturbances in the hand can be demonstrated as well as loss of sensation of the ulnar palmar aspect of the hand. Frequently both nerve trunks are divided at the wrist.

Abduction of the little finger is one of the simplest tests for disclosing ulnar nerve paralysis. The abductor and flexor muscles of the little finger abduct this digit from the fourth ray.

Abduction and adduction of the fingers, excluding the thumb, form a very reliable test for the ulnar nerve function. A test may be done with the examiner using his own hand for a test object or the study may be made using a sheet of paper between individual fingers. The palmar interossei adduct the fingers to an imaginary line drawn longitudinally through the center of the middle finger and the dorsal interossei abduct the fingers from that line. Inability to do this movement indicates ulnar nerve disruption.

Adduction of the thumb can be used as a test of ulnar nerve paralysis. Ulnar and palmar adduction of the thumb chiefly tests the ulnar nerve. The former calls upon the adductor pollicus and the latter upon the first interossei group.

Complete anesthesia of the sensory area of the ulnar nerve can be demonstrated only if the nerve has been damaged above the bifurcation of the dorsal cutaneous branch, or at the wrist if both the main trunk and the sensory branch have been divided. Damage to either nerve alone will demonstrate sensory changes to the area involved. Evaluation of the sensory changes is most important in ulnar nerve damage in the hand.

The diagnosis of tendon injury is based on functional anatomy concerning the individual units in the hand. For practical purposes there are nine long flexor tendons, namely, the flexor pollicus longus to the thumb and two flexors to each of the remaining four digits. In the hand proper there are nine long extensor tendons, the adductor pollicus longus, the extensor pollicus brevis and longus to the thumb, four common extensor tendons to the remaining four digits in addition to the extensor proprius to the index and little fingers. At the wrist

three additional tendons must be considered, namely, the extensor carpii radialis longus and brevis and the extensor carpii ulnaris. The exact diagnosis of tendon division can be established by testing specific muscle function of each individual tendon named. This statement conveys simplicity but in actual practice becomes complicated due to a multiplicity of factors already mentioned.

Failure to make an immediate diagnosis of nerve and tendon injury is a common pitfall in the management of wounds of violence in the hand. Too frequently treatment is begun before an adequate examination of the involved part has been made. Puncture and gunshot wounds are often merely dressed and lacerations, both superficial and deep, are treated by simple closure of the skin after hemostasis has been secured. Under these circumstances the patient may be the first to direct the physician's attention to a disturbance of function in his hand.

TREATMENT

In general, we[6] advocate primary tenorrhaphy and neurorrhaphy with certain exceptions to this principle.

When nerve and tendon are divided in the digit, from the metacarpophalangeal joint distalward, *Zone 1*, primary tendon repair within the narrow, fibrous, flexor sheath becomes the major issue. Here we may elect secondary tenorrhaphy with or without tendon graft.[1] In any event the digital nerve is repaired at the time of tenorrhaphy. In the palmar area, *Zone 2*, from the distal edge of the transverse volar ligament to the metacarpophalangeal joint, primary tenorrhaphy and neurorrhaphy are the procedures of choice. This same principle obtains for combined nerve and tendon injury located in the region from the distal edge of the transverse volar ligament proximalward, designated as *Zone 3*.

The second general consideration is based on time; the interval between injury and surgical care of the wound. In our clinic we[5, 7] advocate conversion of the contaminated wound to a clean surgical wound provided the technic is started within the first 6 hours after injury. When factors beyond the control of the surgeon preclude application of this principle the wound should be cleansed, devitalized tissue and foreign body removed, and the skin edges approximated after securing hemostasis. Definitive treatment then is classified as a secondary procedure and should be done at the earliest possible date.

In the operating room with the patient under general anesthesia the surgical procedure of neurorrhaphy and tenorrhaphy is done in a bloodless field by proper application and use of the pneumatic tourniquet. For best results certain fundamental principles of surgical technic are followed, namely:

1. Conversion of a contaminated wound into a clean surgical wound.
2. Removal of all dirt and foreign material from the wound.
3. Debridement of all devitalized tissue from the wound.
4. Insurance of complete hemostasis in the wound.
5. Accurate anatomic reconstruction of divided nerve and tendon.

More frequently than not the wound of violence is lengthened by properly placing the distal and proximal arms in physiologic planes. By identification of

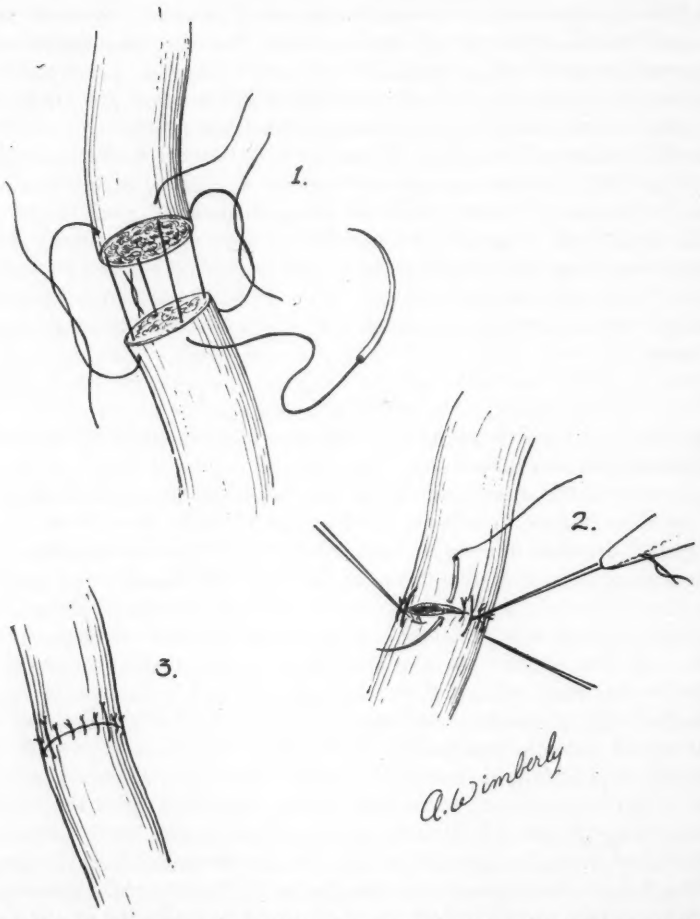

FIG. 3. Drawing demonstrating technic of nerve repair with multiple interrupted sutures of silk.

normal tissue one can easily delineate the point of division of nerve and tendon.

Tenorrhaphy usually is done before repair of the divided nerve and in the large percentage of our cases the technic of Koch-Mason-Allen[4] has been used. On occasion the Lange or Bunnell suture of silk has replaced the first one mentioned.

We prefer multiple interrupted silk sutures in the repair of severed nerves. Nerve trunks usually are sutured by placing four interrupted 4-0 silk sutures at the four major points of the circumference and by approximating the perineurium tightly between these four points using interrupted sutures of either

5-0 or 6-0 silk (fig. 3). In the smaller branches, the volar digital or digital nerves, interrupted sutures of 5-0 or 6-0 silk only are required to approximate the perineurium.

In neurorrhaphy, as in tenorrhaphy, the line of suture is important and healing progresses best without any tension. Neurolysis may be necessary to remove tension. Proper flexion of the hand on the wrist and the phalanges on the metacarpal bones aid in reduction of excess strain on the suture line. The ideal position can be maintained by intelligent splinting of the hand and forearm. Primary neurorrhaphy affords immediate continuity of the damaged nerve; early regeneration of the axones is made possible, a period of delay in observation is obviated and the complication of neuroma is lessened (fig. 4).

Postoperative care includes attention to all factors which promote healing of the wound with minimal complications. The position of the hand to afford comfort and optimum flow of blood to the part is important. Antitetanus therapy is given as indicated. Chemotherapy is instituted using penicillin for 6 to 10 days in a dosage of 300,000 or more units daily. Other antibiotics may be indicated in selected cases. In delayed or secondary neurorrhaphy, bacterial culture from the initial wound may indicate the specific antibiotics to be used preoperatively and postoperatively. Careful toilet of the wound during dressing and reapplication of a splint as needed are important features of postoperative care. Finally, protective support of the paralyzed muscles and adequate follow-up examinations with directed physical therapy are the avenues which lead to a successful functional result.

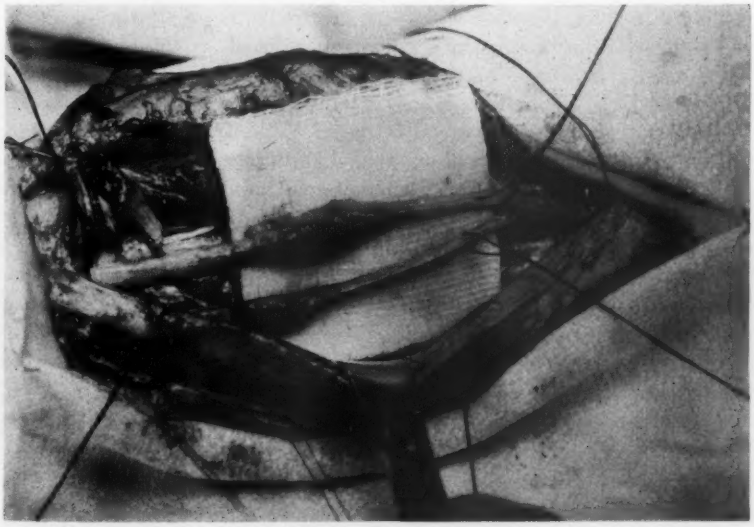

FIG. 4. Example of neuroma formation following division of ulnar nerve and its dorsal cutaneous branch. Primary neurorrhaphy had not been done.

MATERIAL AND RESULTS

From 1941 to 1955 (inclusive) 107 patients with combined nerve and tendon injury in the hand and forearm (table I) were treated at the Cincinnati General Hospital and observed periodically in the Hand Clinic. In this group of patients, 70 (65 per cent) were males and 37 (35 per cent) were females.

Since the site of injury to nerve and tendon may influence the final result, anatomic division occurred as follows: 17 cases (16 per cent) fell in Zone 1, 19 cases (18 per cent) were in Zone 2, 69 cases (64 per cent) occurred in Zone 3 and 2 cases (2 per cent) had damage in more than one zone. These figures substantiate the clinical impression generally believed that nerve and tendon division occur more frequently about the wrist (Zone 3) than elsewhere in the hand.

If one case (No. 44) is deleted from the series of patients with injuries in Zone 3, the remaining 68 cases can be studied in relationship to frequency of injury to the individual nerves or combinations. In 26 cases (38 per cent) the ulnar nerve alone was divided; in 24 cases (35 per cent) the median nerve alone was damaged; in 11 cases (16 per cent) the median and ulnar nerves were injured while in only 7 (10 per cent) the dorsal cutaneous radial nerve was severed. These figures suggest less chance (more than 50 per cent) of dividing both nerves at the wrist as compared to injury of either nerve alone.

As previously stated we advocate primary neurorrhaphy and tenorrhaphy when circumstances permit. Of the 107 cases, 94 patients (88 per cent) had definitive primary repair and the remaining 13 (12 per cent) had secondary repair or declined this advice.

In such a group of cases "follow-up study" is not easy to evaluate and accurate scientific calipers for a perfect survey of such patients is lacking. In addition, there are many other factors influencing results, such as the number of individual surgeons involved. More than 25 Surgical Residents performed the operations on these 107 patients whose cases are reported. Because of the many variables a statistical analysis would be meaningless, if not impossible.

Arbitrarily, the cases have been divided into two categories, "good" and "poor" results. If a patient failed to return to clinic for periodic observation less than 4 months after operation, this case was placed in the "insufficient follow-up" group.

By *good result* the patient has at least 75 per cent or more normal function of the involved hand. The patient is able to work, has a functioning unit and demonstrates no serious sequela from the injury. By *poor result* the patient has less than 75 per cent normal function of the involved hand. This hand is not a functioning unit, the patient cannot retain his usual occupation and frequently is considered an industrial risk. Using these broad criteria 73 patients (82 per cent) had a good result and 16 (18 per cent) had a poor result.

Of the 89 cases which permitted adequate follow-up study the end result by zone survey is shown (table II). These data confirm our previous study and clinical impressions of the poor results obtained by primary tenorrhaphy, in general, when the injury occurs within the narrow, fibrous, flexor tendon sheath

TABLE I

Combined nerve and tendon injuries

	Name	Number	Sex	Date of Injury, Diagnosis	Zone	Definitive Treatment	Result
1	J. W.	163012	M	8/23/41 Median n. Ulnar n. F. carpii ulnaris F. carpii radialis C. ext. L2-3-4-5	2-3	Primary repair. Secondary repair—12/8/41	Poor
2	P. M.	11139	M	8/26/41 Ulnar n. F. carpii ulnaris	3	Primary repair	Good
3	J. M.	163182	M	8/30/41 Median n. F. carpii radialis P. longus	3	Primary repair	Good
4	F. R.	11082	F	8/31/41 D. cutaneous radial n. Abductor pollicus longus	3	Primary repair	Good
5	D. M.	165317	M	10/17/41 Ulnar n. Median n. F. pollicus longus F. carpii radialis F. d. sublimus R4-5 F. d. profundus R4-5 P. longus	3	Primary repair	Good
6	B. S.	165518	M	10/20/41 Ulnar n. F. carpii ulnaris F. d. sublimus L4-5 F. d. profundus L4-5	3	Primary repair	Good
7	V. B.	165957	F	11/1/41 Ulnar n. F. carpii ulnaris F. d. sublimus R4-5 F. d. profundus R5	3	Primary repair	Poor
8	E. S.	167797	F	1/3/42 Median n. F. carpii radialis F. d. sublimus R2-3-4 P. longus	3	Primary repair	Good
9	A. L.	158530	F	1/11/42 Median n. F. carpii ulnaris F. d. sublimus R2-3-4-5 F. d. profundus R2-3-4-5 P. longus	3	Primary repair	No follow-up
10	E. C.	168137	M	November 1941 Ulnar n. F. d. sublimus L4-5 F. d. profundus L4-5	3	Initial treatment elsewhere. Secondary repair—2/25/42	Good
11	M. A.	132362	F	3/9/42 Median n. P. longus	3	Primary repair	Good
12	M. U.	147737	F	6/14/42 Median n. F. carpii radialis F. d. sublimus R3-4 P. longus	3	Primary repair	Good
13	P. M.	11379	M	9/5/42 Ulnar n. F. carpii ulnaris	3	Primary repair	No follow-up
14	S. B.	715023	M	9/11/42 Median n. F. pollicus longus F. d. sublimus R2-3 F. d. profundus R2-3 P. longus	3	Primary repair	No follow-up
15	J. H.	184673	M	6/21/43 Ulnar n. F. d. sublimus R5 F. d. profundus R5	3	Primary repair	Good
16	G. C.	187563	F	2/15/44 Ulnar n. F. carpii ulnaris	3	Primary repair	Good
17	W. M.	159894	F	3/27/44 Ulnar n. F. d. sublimus R4-5 P. longus	3	Primary repair	Good
18	L. A.	164636	F	4/29/44 Digital ulnar n. F. d. profundus R5	1	Primary repair	Good

TABLE I—*Continued*

	Name	Number	Sex	Date of Injury, Diagnosis	Zone	Definitive Treatment	Result
19	A. C.	194204	F	6/2/44 Median n. Ulnar n. F. pollicus longus F. d. sublimus R2-3-4-5 F. d. profundus R2-3-4-5 F. carpii radialis F. carpii ulnaris P. longus	3	Primary repair	Poor
20	M. S.	196879	F	9/18/44 Ulnar n. F. d. sublimus R4-5 F. d. profundus R4-5	3	Primary repair	Poor
21	W. W.	197660	M	10/18/44 Volar digital ulnar n. F. d. sublimus R4-5 F. d. profundus R4-5	2	Primary repair	Good
22	J. S.	96310	M	11/6/44 Median n. Ulnar n. F. carpii ulnaris F. carpii radialis F. d. sublimus L2-3-4-5 F. d. profundus L2-3-4-5 P. longus	3	Primary repair	Good
23	M. M.	72089	F	11/19/44 Median n. F. pollicus longus P. longus	3	Primary repair	Good
24	E. D.	200743	F	2/18/45 D. cutaneous radial n. Ext. carpii radialis longus Ext. carpii radialis brevis	3	Primary repair	Good
25	F. P.	211562	M	3/18/46 Ulnar n. F. carpii ulnaris F. d. sublimus L5 F. d. profundus L5	3	Primary repair	Good
26	C. B.	212419	M	4/3/46 Median n. F. d. sublimus R2-3-4 F. d. profundus R2-3-4 F. pollicus longus R1 P. longus Ext. carpii radialis longus and brevis	3	Primary repair	Good
27	R. G.	212898	M	4/4/46 Volar digital median n. F. pollicus longus L1	2	Primary repair	Good
28	J. D.	213068	M	4/26/46 Digital ulnar n. F. d. sublimus L5 F. d. profundus L5	1	Primary repair	Poor
29	L. S.	213550	M	5/3/46 Ulnar n. F. d. sublimus L4-5 F. d. profundus L4-5	3	Primary repair	Good
30	D. G.	213790	M	5/12/46 Ulnar n. F. carpii ulnaris F. d. sublimus R2-3-4 F. d. profundus R3	3	Primary repair	Good
31	J. G.	213907	M	5/19/46 Volar digital median n. F. d. sublimus and profundus R2	2	Primary repair	Good
32	J. A.	215885	M	7/18/46 Dorsal cutaneous radial n. F. carpii radialis Abductor pollicus longus Ext. pollicus brevis	3	Primary repair	Good
33	L. H.	216541	M	8/11/46 Volar digital median n. F. pollicus longus	2	Primary repair	Good
34	E. N.	216603	M	8/15/46 Volar digital ulnar n. Abductor m. d. q. R5 Flexor m. d. q. R5	2	Primary repair	Good
35	D. S.	159876	M	9/1/46 Ulnar n. F. carpii ulnaris P. longus F. d. sublimus R3-4-5 F. d. profundus R4-5	3	Primary repair	Good

TABLE I—*Continued*

	Name	Number	Sex	Date of Injury, Diagnosis	Zone	Definitive Treatment	Result
36	E. B.	217173	F	9/1/46 Volar digital ulnar n. F. d. sublimus R5	2	Primary repair	No follow-up
37	E. R.	218111	M	9/13/46 Ulnar n. F. carpii ulnaris F. d. sublimus R5 F. d. profundus R5	3	Primary repair	Good
38	M. C.	150941	M	1/1/47 Volar digital median n. F. d. sublimus L3 F. d. profundus L3	2	Primary repair	Good
39	W. F.	217981	M	1/3/47 Volar digital ulnar n. F. d. sublimus L4	2	Primary repair	No follow-up
40	D. W.	221457	M	1/14/47 Digital median n. F. d. profundus L3	1	Primary repair	Poor
41	T. G.	221925	M	1/26/47 Median n. F. carpii radialis Fractures of radius and ulna	3	Primary repair	Good
42	E. S.	222138	M	2/1/47 Median n. F. d. sublimus L2 F. d. profundus L2 P. longus	3	Primary repair	Good
43	E. R.	201114	M	2/3/47 Median n. F. d. sublimus L2 F. d. profundus L2 P. longus	3	Primary repair	Good
44	J. A.	180896	M	5/30/47 Radial n. Triceps tendon	3	Primary repair	Good
45	V. M.	221514	F	6/14/47 Median n. Ulnar n. F. d. sublimus R5 F. d. profundus R5 P. longus	3	Primary repair	Poor
46	J. B.	228545	M	8/10/47 Ulnar n. F. carpii ulnaris F. d. sublimus R4-5 F. d. profundus, R4-5	3	Secondary repair (alcoholism) 1/23/48	Poor
47	E. W.	183930	F	11/15/47 Ulnar n. F. d. sublimus R4	3	Primary repair	Good
48	R. E.	237349	F	4/11/48 Median digital n. F. d. sublimus R3-4-5 F. d. profundus R4	1	Primary repair	No follow-up
49	R. M.	224952	F	4/13/48 Ulnar digital n. F. d. sublimus L5 F. d. profundus L5	1	Primary repair	Good
50	M. R.	182206	M	6/2/48 Median volar digital n. Ulnar volar digital n. F. d. sublimus R2-4 F. d. profundus R2-4	2	Primary repair	Good
51	A. B.	45089	M	7/4/48 Median volar digital n. Ulnar volar digital n. F. d. sublimus R2-3-4-5 F. d. profundus R2-3-4-5	2	Not repaired (alcoholism)	No follow-up
52	D. K.	243045	M	9/28/48 Ulnar n. F. carpii ulnaris F. d. sublimus muscle	3	Primary repair	Good
53	K. McM.	204565	F	12/20/48 Ulnar n. F. carpii ulnaris	3	Primary repair	Good
54	S. T.	110491	M	3/4/49 Volar median n. F. pollicus longus	2	Primary repair	Poor
55	C. C.	252971	F	6/30/49 Volar digital ulnar n. F. d. sublimus L4-5 F. d. profundus L4-5	2	Primary repair	Good

TABLE I—*Continued*

	Name	Number	Sex	Date of Injury, Diagnosis	Zone	Definitive Treatment	Result
56	P. S.	181336	F	3/13/49 Median volar digital n. F. d. profundus L2	1	Primary repair	Good
57	H. McD.	226618	M	8/27/49 Median n. F. d. sublimus R3 F. d. profundus R3 P. longus	3	Primary repair	No follow-up
58	B. S.	255161	F	8/27/49 Median n. F. d. sublimus R3 F. d. profundus R3 P. longus	3	Primary repair	No follow-up
59	D. D.	195400	M	9/24/49 Ulnar volar digital n. C. extensor R4-5	2	Secondary repair—11/12/49	Good
60	E. A.	212116	M	11/9/49 Median n. D. cutaneous radial n. F. carpii radialis Ext. carpii radialis longus F. d. sublimus R2-3-4-5 F. d. profundus R2-3 P. longus	3	Primary repair	Good
61	T. N.	167899	M	12/17/49 Median n. F. d. sublimus R2-3-4 F. d. profundus R2-3-4 F. carpii radialis P. longus	3	Primary repair	Poor
62	L. McG.	259688	M	1/22/50 Median n. F. d. sublimus R2-3-4-5 F. d. profundus R2-3-4-5	3	Primary repair	Good
63	W. McF.	259609	M	August 1947 Volar digital median n. F. d. sublimus R2 F. d. profundus R2 F. pollicus longus R1	3	Initial treatment elsewhere No surgery	No follow-up
64	L. R.	265075	M	6/27/50 Ulnar n. F. carpii ulnaris F. d. sublimus R3-4-5 P. longus	3	Primary repair	Good
65	A. S.	265623	M	7/11/50 Ulnar n. F. carpii ulnaris P. longus	3	Primary repair	Good
66	J. S.	267147	M	8/18/50 Median n. F. d. sublimus R2-3-4 F. d. profundus R3-4 P. longus	3	Primary Repair	No follow-up
67	J. Y.	191560	M	8/26/50 Digital ulnar n. F. d. sublimus L5 F. d. profundus L5	1	Primary repair	Good
68	E. R.	272502	F	3/4/51 Digital median n. F. d. sublimus R3 F. d. profundus R3	1	Wound closed Advised secondary repair	No follow-up
69	J. C.	235685	M	4/25/51 Median n. Ulnar n. F. carpii radialis F. carpii ulnaris F. d. sublimus L2-3-4-5 F. d. profundus L2-3-4-5 F. pollicus longus P. longus	3	Primary repair; cervico-thoracic sympathectomy—4/28/51	Good
70	F. B.	269857	M	2/1/52 Ulnar n. F. carpii radialis F. carpii ulnaris P. longus	3	Primary repair	No follow-up
71	J. F.	287280	M	6/29/52 Median n. Ulnar n. F. d. sublimus R3-4 F. d. profundus R3-4 F. carpii radialis F. carpii ulnaris P. longus	3	Primary repair	Good

TABLE I—*Continued*

	Name	Number	Sex	Date of Injury, Diagnosis	Zone	Definitive Treatment	Result
72	W. G.	288142	M	8/2/52 Ulnar n. F. d. sublimus R4-5 F. d. profundus R4-5	2	Primary repair	Good
73	W. T.	288908	M	8/29/52 Ulnar n. F. d. sublimus muscle F. carpii ulnaris	3	Secondary repair—9/24/52	No follow-up
74	B. S.	290269	F	10/26/52 Median n. F. carpii radialis P. longus	3	Primary repair	Good
75	J. M.	293622	M	2/12/53 Volar digital median n. F. pollicus longus	2	Advised secondary repair (alcoholism)	No follow up
76	M. D.	294294	F	3/18/53 Median n. F. d. sublimus R3 F. d. profundus R3 F. carpii radialis P. longus	3	Primary repair	Good
77	C. C.	294620	M	3/24/53 Median n. F. carpii radialis F. carpii ulnaris P. longus (both hands)	3	Primary repair	No follow-up
78	R. T.	294656	M	3/27/53 Ulnar n. F. carpii ulnaris F. d. sublimus R4-5	3	Primary repair	Good
79	F. S.	293141	M	4/6/53 D. cutaneous radial n. Ext. pollicus longus	3	Primary repair	Good
80	H. N.	295086	M	4/14/53 Ulnar n. Volar digital median n. F. carpii ulnaris F. d. sublimus R3	2-3	Primary repair	Good
81	M. S.	295528	F	4/29/53 Digital ulnar n. Digital median n. F. d. sublimus R3-4-5 F. d. profundus R3-4-5	1	Primary repair	Poor
82	A. H.	243751	F	5/30/53 Ulnar n. F. carpii ulnaris	3	Primary repair	No follow-up
83	J. E.	297272	M	7/2/53 Digital median n. F. d. profundus R2	1	Primary repair	Good
84	D. S.	291684	F	7/3/53 Median n. F. carpii radialis F. d. sublimus R2-3 F. d. profundus R2 P. longus	3	Primary repair	Good
85	T. P.	275342	M	7/4/53 Median n. F. carpii radialis F. pollicus longus P. longus	3	Primary repair	Good
86	D. S.	299456	F	9/24/53 Median n. F. carpii radialis P. longus	3	Primary repair	Good
87	H. R.	303709	F	2/19/54 Volar digital median n. F. d. sublimus R4 F. d. profundus R4	2	Primary repair	No follow-up
88	N. B.	287823	F	3/7/54 Digital median n. F. d. sublimus L4 F. d. profundus L4	1	Secondary repair—4/25/54	Poor
89	H. D.	304584	M	3/24/54 Digital ulnar n. F. d. sublimus L5 F. d. profundus L5	1	Primary repair	Poor

TABLE I—*Continued*

	Name	Number	Sex	Date of Injury, Diagnosis	Zone	Definitive Treatment	Result
90	E. P.	148152	M	3/26/54 Digital median n. F. d. profundus L2	1	Primary repair	Good
91	V. W.	17447	M	4/20/54 D. cutaneous radial n. C. ext. L3	3	Primary repair	Good
92	G. H.	306701	M	5/27/54 Median n. F. carpii radialis F. carpii ulnaris P. longus	3	Primary repair	Good
93	A. T.	242649	F	5/29/54 Median n. Ulnar n. F. d. sublimus R2-3-4-5 F. d. profundus R2-3-4-5 P. longus	3	Primary repair	Good
94	W. R.	43042	M	6/19/54 Digital ulnar n. F. d. sublimus R4-5 (partial)	1	Primary repair	Good
95	W. J.	308165	M	7/2/54 Median n. Ulnar n. F. carpii ulnaris P. longus	3	Secondary repair—9/4/54	Good
96	A. G.	309346	F	8/24/54 Median n. F. carpii radialis P. longus	3	Primary repair	Good
97	H. W.	45632	M	8/31/54 Median n. Ulnar n. F. d. sublimus muscle F. d. profundus muscle	3	Initial treatment elsewhere. Secondary repair—5/19/55	Poor
98	D. A.	310442	F	9/26/54 Volar digital median n. F. pollicus longus L1	2	Primary repair	Good
99	F. C.	312517	M	11/30/54 Volar digital median n. F. pollicus longus L1	2	Primary repair	Good
100	S. B.	226341	F	12/31/54 Digital median n. F. d. sublimus R2 F. d. profundus R2	1	Secondary repair—3/11/55	Poor
101	E. R.	137101	M	1/1/55 Digital ulnar n. F. d. sublimus R4-5 F. d. profundus R4-5	1	Primary repair	Poor
102	B. W.	317867	F	5/21/55 Volar digital ulnar n. F. d. sublimus L4-5 F. d. profundus L4-5	2	Secondary repair	Good
103	R. L.	310544	F	5/22/55 D. cutaneous radial n. Ext. pollicus longus Ext. pollicus brevis	3	Primary repair	Good
104	C. M.	210694	M	8/13/55 Median n. Ulnar n. F. d. sublimus R2-3-4-5 F. d. profundus R2-3-4-5 P. longus	3	Primary repair	Good
105	J. G.	238450	M	8/13/55 Digital ulnar n. F. d. profundus	1	Primary repair	Good
106	J. D.	275587	M	9/22/55 D. cutaneous ulnar n. Ext. proprius m. d. q.	3	Primary repair	Good
107	J. T.	150937	M	9/30/55 Ulnar n. F. d. sublimus muscle F. carpii ulnaris muscle	3	Primary repair	Good

TABLE II

Zone survey—data and results

Zone	No. Cases Available for Study	No. Cases Good Result	Per cent Good Result
1	15	8	53%
2	14	13	93%
3	58	51	88%
Combined	2	1	50%
Total	89	73	82%

in the digit, Zone 1. It is here tendon injury remains the paramount issue and digital nerve injury is secondary.

SUMMARY

Combined nerve and tendon injuries in the hand and forearm are a challenge to those surgeons who accept the responsibility of their repair and who desire a good functional result. Of the many factors concerned with this problem, emergency care, accurate preoperative diagnosis and definitive treatment have been emphasized in this discussion.

A survey of 107 cases of combined nerve and tendon injuries has been submitted for analysis and the data has confirmed some of our clinical impressions Nerve and tendon injuries were seen more frequently at the wrist (Zone 3) than elsewhere in the hand. Primary repair afforded good to excellent results when the injury was confined to either Zone 2 or Zone 3; however, the results were poor when the injury occurred in Zone 1. Combined nerve and tendon injuries in Zone 1 has been a serious problem and in the future better functional results will be dependent, perhaps, upon improved methods of secondary repair either with or without tendon transplant.

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EXPERIENCES WITH VAGINAL HYSTERECTOMY AT THE CINCINNATI GENERAL HOSPITAL: A TEN YEAR STUDY

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The high incidence of pelvic tumors, pelvic infection, and other major pelvic pathology is frequently a deterrent to vaginal surgery on the gynecology service of a general hospital. However, a definite effort is made to provide adequate experience in this type surgery. The vaginal approach to pelvic surgery has become increasingly popular, both abroad and in this country, so that a great number of papers have appeared in the literature in recent years. This report is a review of the experience in vaginal hysterectomy at the Cincinnati General Hospital during the past 10 years, 1946–1955.

Soranus,[4] a prominent obstetrician in Rome, between 100–200 A.D. is credited with the first idea of removing the uterus by the vaginal route. The first authentic description of the vaginal removal of the uterus came from Berengareus[4] of Bologna in 1507. However, the first actual deliberate and well planned vaginal hysterectomy for carcinoma in a prolapsed uterus was performed by Langenbeck[4] of Gottingen in 1813. The second complete vaginal hysterectomy without uterine prolapse was done by Sauter on Jan. 28, 1822. There was little standardization in technic until the Mayo[2] operation was published in 1915. The basic principle in this technic was approximation of the broad ligaments to support the bladder.

Probably the greatest influence toward vaginal hysterectomy in this country has come from Heaney[3] and Allen[1] of Chicago. The technic for vaginal hysterectomy at this hospital, for the most part, has been basically that of the Chicago group, and the fundamental principles regarding indications and contraindications have been adhered to. The cases have been supervised by different members of the attending staff and, as a result, various technics have been used.

The main variations have been the method of closure of the peritoneal cavity and construction of support to the bladder and pelvic floor. In some instances the Heaney technic was used, anchoring the supporting ligaments to the angles of the vaginal vault. Also, variations of the Mayo technic of suturing the broad ligaments together in the midline to support the bladder and pelvic floor were used.

Throughout the years, one of the main indications for vaginal hysterectomy has been uterine prolapse. It has been thought that the logical approach to relaxation of the pelvic floor is by way of the vagina. Vaginal hysterectomy however, may or may not be a required part of the operation for reconstruction of the support of the pelvic floor. One must keep in mind that simple removal of the uterus is not effective treatment for prolapse.

The illustrations pictured here show one technic that was used in the treat-

ment of uterine prolapse by vaginal hysterectomy with anterior and posterior colpoperineoplasty that proved to be very successful.

There is a preponderance of Negro patients on the gynecology service at the Cincinnati General Hospital and many of these patients have large pelvic tumors or pelvic infection. These conditions are frequently contraindications to surgery by the vaginal route. There are, consequently, some restrictions in the number of patients in whom vaginal hysterectomy is considered the treatment of choice. There is, however, evidence of an increasing yearly incidence of vaginal hysterectomy at this hospital. The procedure was carried out on 6 patients in 1946. The peak incidence was 44 in 1952. The average number done per year was 19.4. There were 2 patients who had no previous pregnancies.

Most of the patients in this series were in the middle age group. The greatest age incidence 70, fell between 40–50 years. There were 2 patients between 20–30 years and 12 between 70–80 years. More conservative management has frequently been found to be more desirable in the young or the aged.

The symptoms that were presented by the majority of patients were the result of a defect in support of the bladder and pelvic floor, table I. Abnormal uterine bleeding also was a frequent complaint.

There was no demonstrable uterine prolapse in 40 of the patients. Many of the patients with moderate or severe degrees of uterine prolapse had comparable amount of cystocele and rectocele. This was not always true. Extreme degrees of uterine prolapse are not necessarily accompanied by large cystocele and rectocele, and conversely, prolapse of the uterus is not always present with cystocele and rectocele. The evaluation of the interpretation of different observers regarding severity of vaginal relaxation is most difficult. An effort was made to consider the most reliable examination of the patients in this group and is shown in table II.

In most of the aged patients with uterine prolapse, the vaginal tissues frequently show evidence of senile changes. The tissues are dry, thin, very friable, and at times ulcerations were present. A definite effort was made to correct these conditions by reducing the prolapse and using local applications of estrogenic cream. At times complete bed rest was necessary to accomplish this before the patient was considered completely prepared for vaginal surgery.

Previous pelvic surgery has long been considered a contraindication to vaginal hysterectomy. This is not always a hard and fast rule, however, and the vaginal approach might still be the best for the patient in spite of previous surgery. One hundred and two of the patients in this group had no previous pelvic surgery. Many of the patients had a dilatation and curettage with one or more biopsies of the cervix for abnormal bleeding before the vaginal hysterectomy was done. Other procedures were uterine suspension, tubal ligation, unilateral removal of a tube and ovary, vaginal and cervical repairs, and radium implantation for bleeding.

The previous local surgery did not interfere with the accessibility to the pelvic organs through the vagina.

There were numerous serious preoperative medical problems such as hyper-

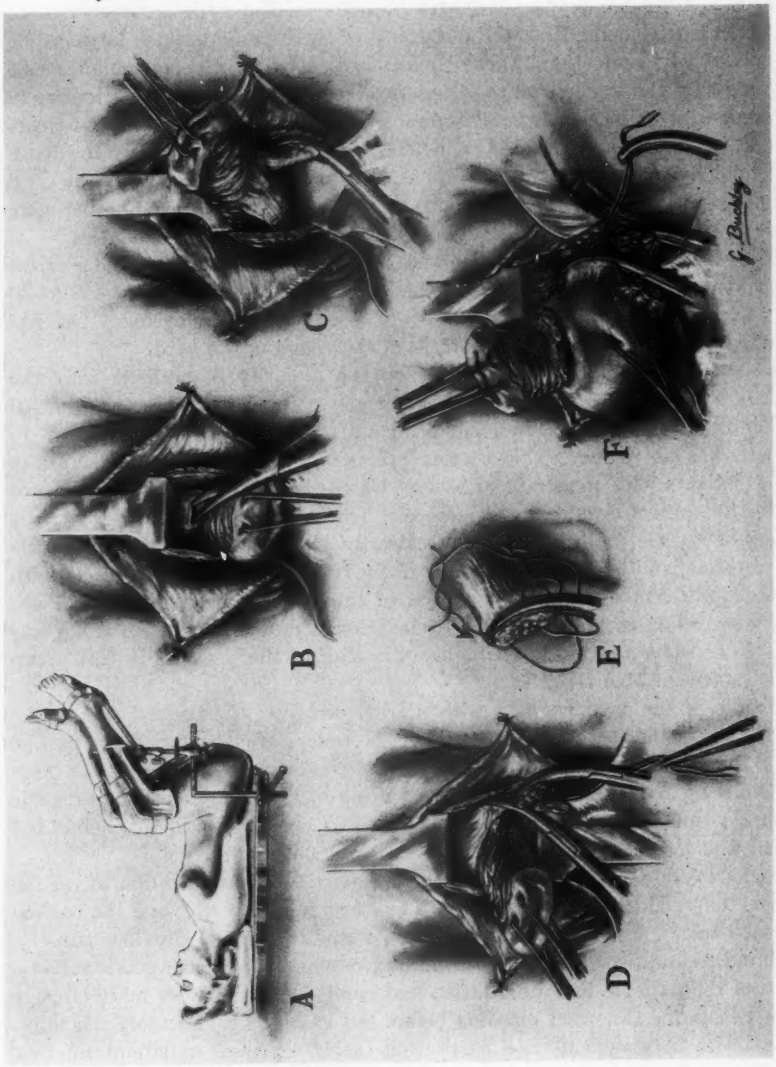

FIG. 1. A: Position of the patient on the operating table. B: Opening of the anterior cul-de-sac. C and D: Ligation of the uterosacral ligaments, cardinal ligaments and the uterine vessels. E: Heaney transfixion suture. F: Ligation of the upper broad ligament.

Ligation of the upper broad ligament.

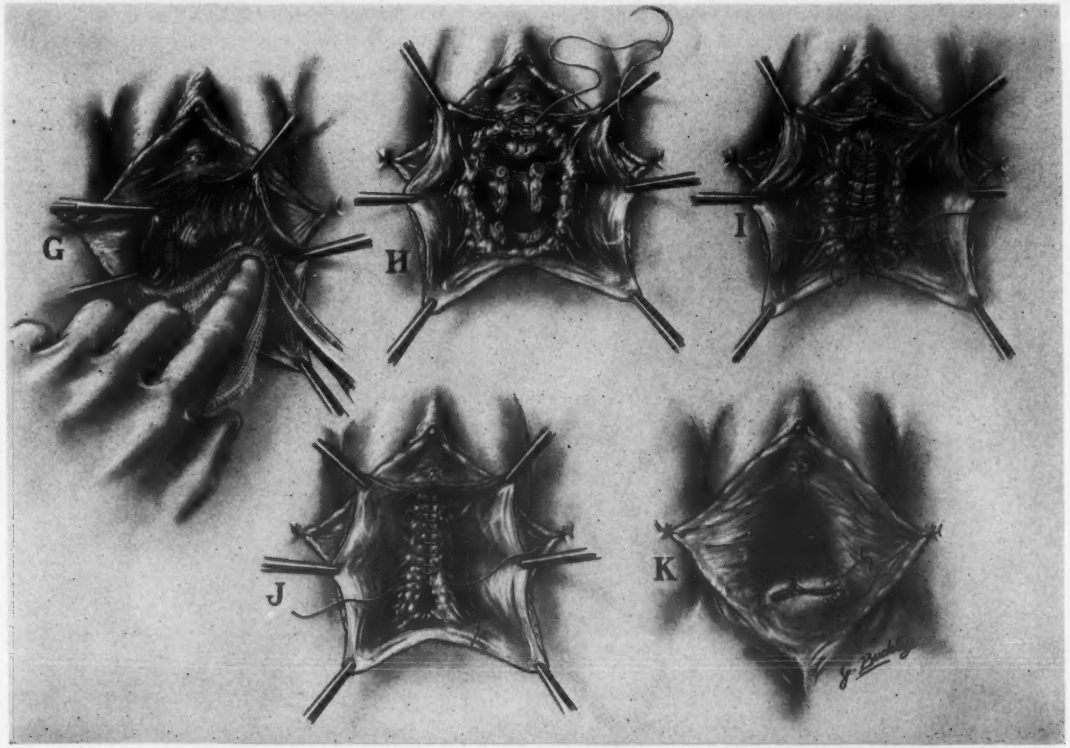

FIG. 2. G, H and I: Approximation of the broad ligaments in the midline, closing the peritoneal cavity and supporting the bladder. The cul-de-sac is closed with a separatepurse-string suture. J and K: Completing the anterior repair.

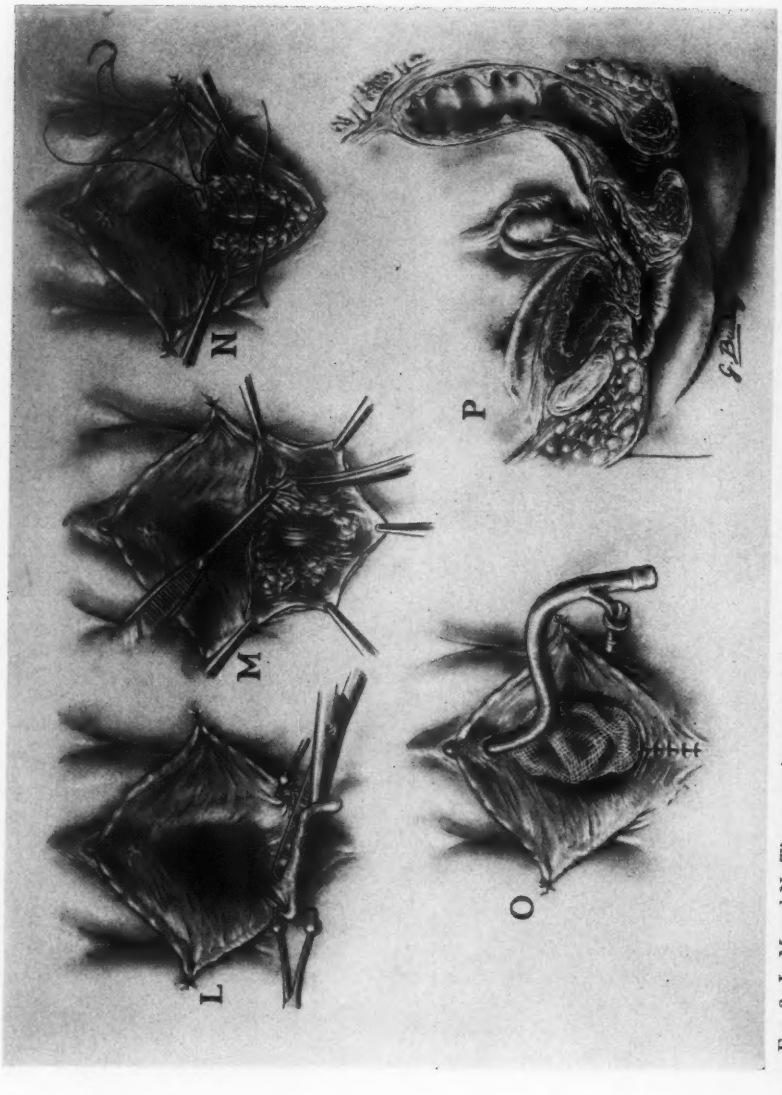

FIG. 3. L, M and N: The posterior veginal repair. O: Vaginal pack and Foley retention catheter. P: Sagittal section showing the end result.

TABLE I

Presenting symptoms

Complaints	Number of Patients
None	5
Prolapse	105
Stress incontinence	81
Pelvic pressure (bearing down)	16
Abnormal bleeding	59
Frequency, urgency, difficulty voiding	9
Back pain	3
Abnormal bowel function	7
Vaginal discharge	2

TABLE II

Physical findings

	Number of Patients
Prolapse	
None	40
1 degree	29
6 degrees	56
3 degrees	69
Cystocele	
None	20
1 degree	29
2 degrees	73
3 degrees	72
Rectocele	
None	18
1 degree	60
2 degrees	79
3 degrees	37

tensive cardiovascular disease in 4 patients, severe diabetes in 13, pulmonary tuberculosis in 3, and extreme obesity in 2. Many of the patients on the gynecology service have medical complications of lesser degree than those mentioned. These increase the risk of any type surgery and necessitate careful study and preparation of the patient.

The type of operation which was carried out in the series is listed in table III. Vaginal hysterectomy alone was performed on 9 patients. The indications for the procedure were abnormal uterine bleeding in 9; preinvasive carcinoma of the cervix in 2; third degree prolapse in 1. A Kelly type plication of the urethra was performed with each anterior wall dissection, i.e. in 167 patients. The operative complications aside from bleeding were few. The rectum and the bladder were each opened one time. Both accidents occurred in the same patient.[1] The defects were promptly recognized and dealt with resulting in no further postoperative difficulties.

TABLE III

Type of operation

Operation	Number of Patients
Vag. Hyst.	9
Vag. Hyst. & ant. vag. rep.	2
Vag. Hyst. & post. vag. rep.	18
Vag. Hyst. ant. & post. rep.	165
Vag. Hyst. ant. & post. rep. one S & O	3
Vag. Hyst. ant. & post. rep. bilat. S & O	2
Vag. Hyst. ant. & post. rep. 3 deg. perin. tear	3
Vag. Hyst. ant. & post. rep. recto-vag. fist.	1
Vag. Hyst. ant. & post. rep. rectal prolapse	1
Vag. Hyst. ant. & post. rep. with morcellation of large fibroid	2

TABLE IV

Pathology	Number of Patients
Myomata uteri	30
Adenomyosis	13
Endometrial polyp	11
Preinvasive carcinoma of the cervix	8
Ovarian cyst, simple serous	2
Adenocarcinoma of the cervix	1
Squamous cell carcinoma of the cervix	1
Pregnancy, intrauterine	1

Chronic cervicitis and the various phases of the endometrium were the common findings in the removed specimens. More complicated abnormalities were noted according to table IV.

The adenocarcinoma of the cervix was unsuspected. It occurred in a 77 year old patient who had a third degree prolapse. There was no bleeding and was missed with curettage. No recurrence has been noted after 2½ years. The patient with the squamous cell carcinoma of the cervix was 73 years old. She had a complete prolapse with a large enterocele. The tumor was well circumscribed, about 1.5 cm. in diameter, and very well differentiated. It was removed with a wide margin. The patient has done well after 2 years with regard to the tumor. The pregnancy occurred in a completely blind patient who was 42 years old and had 10 living children. It was early and not diagnosed.

The postoperative morbidity was never disturbing. Seventy-two patients were afebrile, 93 others ran a low grade febrile course not over 30 days.

Antibiotics were not used in 22 patients. We thought that their use in the remaining 172 was unnecessary. The employment of these agents did not appear to influence the morbidity in those patients who had extensive dissections. No estrogens in any form were used postoperatively to stimulate wound healing.

In general, it was our policy to practice early ambulation. One hundred and sixty-three of the 194 patients were out of bed by the fourth day. There

were no ill effects. There was one death in the series for a mortality rate of 0.51 per cent. The patient was 64 years old with a third degree prolapse, rectocele and cystocele associated with post menopausal bleeding. A preliminary dilatation and curettage revealed negative curettings. Shortly after the vaginal hysterectomy and repair, a mediastinal abscess developed which was drained. However, the patient died on her thirty-second day. Autopsy revealed a perforation of the esophagus, apparently the result of an error in intubation during anesthesia. The death was preventable.

Blood loss during and after the operation was the most frequent complication. The average measured loss during the operation by weighing sponges in 22 patients was 700 cc. This was markedly influenced by the results in 3 patients. In those patients with excessive loss of blood or in those who underwent extensive surgery, blood was given. In addition, 24 1 unit transfusions were administered. It was thought strongly that many were not necessary. Moderate blood loss is well tolerated in patients who are in good condition. In addition, there is no delay in wound healing or increase in operative morbidity.

The possible risk to the patient in the administration of the 1 unit "*prophylactic*" transfusion far overbalances the questionable value. In an effort to better control bleeding, pitocin was injected into the parametria at the start of the dissection.

Early postoperative hemorrhage took place in 1 patient. The pedicle of one uterine vessel was not secure. Religation required laparotomy which was promptly performed after the intra-abdominal hemorrhage was recognized.

Delayed bleeding occurred in 7 patients. There were 3 who developed hematomata, 2 perirectal and 1 in the anterior vaginal wall. The hematomata subsided with conservative management. Four patients had bleeding from the wound edges of the repairs. In 2 of them packing was necessary. The vagina was snugly packed at the close of the operation in an effort to help control delayed bleeding.

Other postoperative complications that took place were:

Urinary tract infections	12
Thrombophlebitis	8
Pelvic abscess	1
Perirectal abscess	1

They were managed in the conventional manner. It was interesting to note that a small fishbone was found in the cavity of the perirectal abscess. The care of the bladder was kept as simple as possible. Continuous drainage was carried out by means of a Foley indwelling catheter. The bladder was irrigated twice daily with 1:10,000 Pot. Permanganate solution. The catheter was removed on the fifth to seventh day. Its ultimate removal was governed in a large part by the patient's relative freedom of pain in the operative area.

If the patient was unable to void or did so in small amounts, the Foley catheter was reinserted for another 48 to 72 hours. Volumes of 500 cc. or more of urine in a bladder produce a temporary paralysis which interferes with its ability to

contract normally. Once voiding took place, the bladder was checked for residual urine every 8 hours until 100 cc. or less was obtained on 2 successive catheterizations. The patient was instructed in the performance of perineal exercises after voiding was reestablished.

In general, the late results on subsequent follow-up visits were regarded as reasonably good. Nine patients failed to return to the clinic for reexamination. There were 3 patients with occasional or slight recurrent stress incontinence, not severe enough to be operated upon. No vaginal vault prolapse was observed. Patients with the following recurrent defects were re-operated upon:

Patients	Defects
1	Kelly operation for incontinence
1	Enterocele
3	Rectocele
2	Cystocele
1	Cystocele, rectocele and enterocele
1	Rectocele and enterocele

SUMMARY

This report is a critical analysis of the patients treated by vaginal hysterectomy at the Cincinnati General Hospital during the past 10 years.

This operative procedure is believed to be a valuable part of the teaching of pelvic surgery.

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VENTRAL HERNIAS

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By definition any hernia through the anterior abdominal wall is a ventral hernia. The subject is too broad for a detailed discussion of each hernia in the region but was selected because it permits review of certain anatomic, histologic, pathologic and therapeutic factors which have bearing on the problems related to many hernias.

The surgeon has worked so long with problems resulting from the inadequacies of the human body that it is only natural for him to believe he can improve upon it. In his effort to correct many types of bodily imperfections, from developmental defects to others resulting from diseases or mechanical stresses and abuses, the surgeon has put things together, taken others apart, thrown pieces away, improvised replacements to patch up parts or prop up the whole individual. He has fed everything imaginable to stiffen the weaker spots or to loosen the tight ones. With the advent of the antibacterial drugs to lessen his fears about foreign bodies, it is not surprising that he has gone to the machine shop for spare parts to assist him in his work.

The solution of special problems in surgery has been aided by the surgeon's mechanical resorcefulness, but one must be on guard against overdoing the thing himself or misleading others in that direction. Why is it becoming more the practice to place within hernia wounds such materials as fascia grafts, skin grafts, diced cartilage, tantalum screen, stainless steel mesh, nylon cloth, fortisan fabric, tantalum plate, etc.? The answer given is that the structures are so poor, or the hole is so large that the parts cannot be brought together and closed securely. But only in an exceptional case is the answer sound and occasionally one of these materials may be used to advantage.

Many who write about the substitutes used in the repair of hernias emphasize that they should be reserved for the recurrent hernia, the difficult-to-repair hernia, etc., and then proceed to report cases with their use in primary repair of inguinal or femoral hernias as well. Experimental work will be reviewed to establish tissue tolerance for the materials, while fascial and muscular defects are created in animals and repaired by use of commercial substitutes to prove their effectiveness. In nearly every instance the clinical application will have been to use the material over or under a fascial layer which has been completely approximated by a standard operative procedure. Rarely is a case included in which the substitute was used to patch a defect in the fascia which could not otherwise be closed. Reviews of this nature lead one to believe that principles of repair are being neglected and that material substitutes are being used far more often than necessary.

If the recurrence rates on standard hernioplasties have gone up, perhaps it is because we are slipping in the application of our technical skills. If the re-

currence rates have not gone up and these materials are being added as an extra precaution in all cases to prevent recurrences, we shall certainly sacrifice technical excellence and incur the risk of new complications from the use of additional foreign bodies. If our incisional hernias are on the increase and our abilities for repairing them by standard methods are no longer trustworthy we are guilty of negligence in seeking an understanding of tissue growth and repair.

The time seems appropriate for a review of many factors which contribute to the success or failure of fascial repair. Perhaps the information which follows will be of value particularly to the graduate students of surgery who have not as yet crystalized their ideas on the surgical management of hernias and of fascial incisions of the abdominal wall.

It should be remembered that the only hernia which is benefited by a high ligation of the hernial sac is the indirect inguinal hernia. In the infant and small child this procedure, along with the removal of the vaginal process distal to the ligature, is curative. In the adult it also is usually curative if the area is reinforced by a good fascial repair. In no other hernia of the abdominal wall does the high ligation of the peritoneal pouch contribute anything to the success of the repair. The job to be done is the complete and secure closure of the fascial defect. Failure *can* result from the choice of the operation employed, but much more often will the recurrence of herniation be the result of the *manner* in which the operation is performed. The pitfalls which bring failure to fascial repairs in one area are capable of producing failures in repairs done in other areas.

CAUSES OF IMPERFECTIONS IN FASCIAL REPAIRS IN SURGICAL WOUNDS

A consideration of the causes which commonly account for postoperative hernias, either primary or recurrent, will serve to provide helpful information for their surgical correction. In general, incisional hernias develop because of defections in the healing of the fascial layers. Something happens to allow for a fascial separation. The more common elements responsible for the accident are as follows:

1. *Poor Suture Material*

Suture lines may give way because of a bad choice of suture material. When working with absorbable suture materials, the surgeon should use nothing softer than medium chromic catgut on a fascial closure. One should be sure this is obtained. It is easy for a mistake to be made and one may be given plain or mildly chromicized catgut without being aware of the substitute. These sutures soften before healing has advanced far enough to withstand the strain without assistance from good sutures.

Mistakes can be made in choosing the weight or size of the suture material. While it is true that some variation should depend upon the size of the individual, this does not mean that extremely small sizes are always indicated for use in infants and small children. One should not use suture material lighter than

⅘0000 silk or ⅘000 medium chromic catgut in the fascia layers of an infant. For a child, ⅘000 silk or ⅘00 catgut should be used. Some reduction in the amount of foreign material in the wound can be attained by using very fine material for ligatures.

In the obese or heavily muscled adult one should employ heavier than average suture materials. A doubled suture of ⅘0000 or ⅘000 silk is not as good as a single strand of a heavier grade.

The tissue tolerance of buried fine-wire sutures in the presence of contamination or infection is well known. But the tremendous tensile strength of wire sutures can lead to a false sense of security. Although it is quite true that the patient will not break his buried wire sutures, it also is true that any excess strength beyond that of the tissue in the loops does not strengthen the wound. Since it is known that fine-wire sutures will cut like knives when tension is thrown on the sutured wound, the use of heavier wire is generally recommended, not to gain tensile strength but to reduce the cutting tendency under stress.

2. *Tight Sutures*

The main strength of a surgically repaired wound immediately after operation is provided by the sutures and the suture material. They must hold until organization by the tissue can take over the work. Although cell growth starts immediately, there usually is a delay in the development of tissue strength for nearly one whole week. Between 7 and 10 days the deposition of collagen fibrils begins; and not until then is the strength of the repair benefited by tissue growth. In fact, the tensile strength of surgically repaired wounds actually decreases until about the sixth day. This is the result of softening and degeneration of tissues incorporated in the sutures themselves. It is an obvious fact that to tie down such sutures with great force cannot increase the strength of the suture or the surgical repair of the wound, but will only serve to increase the ischemia of tissue and hasten the completion of the pressure necrosis.

3. *Tissue Tension*

An effect similar to that produced by tight sutures is created by tension or pull on the sutures by the tissues. Surgeons refer to this as a tight closure, a difficult closure, or tension on the suture line. Every abdominal surgeon has observed this effect when he has tried to close a wound while the patient was poorly relaxed. Forceful attempts to draw the fascia together may cause the sutures to tear out of the fascia. A deeper plane of anesthesia eventually makes the closure possible but does not give assurance that the fascial layers will remain in proper relationship to each other. If one suture lets go, others may follow. The possibility is a real one in the type of wound being discussed because the full force of the strain is thrown on the suture line when the anesthetic wears off. It is increased by the patient's apprehension and restlessness and by the surgeon's granting bold physical liberties which impose abnormal and unnecessary stress on the wound.

Straining at defecation or urination and coughing are familiar causes of tension on suture lines but one of the most important causes is postoperative abdominal distention. Delayed use of gastric decompression as well as premature attempts at eating and drinking increase the frequency and severity of this complication. The dilated gastroenteric tract in distending the abdomen also compresses the lungs and increases coughing and throat clearing. Belching, hiccoughs and vomiting added to the list may be the deciding forces to effect the partial separation of the wound even though it may not manifest itself until months later.

4. *Poor Fascial Structures*

When one has trouble closing a wound under tension, much of it is sometimes due to the poor quality of the fascia itself. The likelihood that it may tear under stres makes mandatory good abdominal relaxation at the time of wound closure. When the structures are found to be poor, the patient should be given special consideration during his convalescence. One should be extra careful to protect such suture lines against abnormal tension by avoiding the common errors just mentioned.

5. *Poor Fascial Approximation*

The role played by scar tissue in the development of incisional hernias will be discussed later in this article. However, at this time, your attention is directed to the fact that defects in a poor fascial approximation are always filled in with scar tissue. These defects may arise from the use of too few sutures. Then again, unless a portion of the fascial edge is cleared of adipose tissue, it may become interposed between the fascial edges and serve to weaken the union. The same may happen with muscle tissue.

An abdominal incision made close to the border of the rectus muscle may reveal two free edges for the anterior and posterior sheaths on one side but only one common edge on the other. This usually is repaired as a one-layer closure which is not as strong as a two-layer repair.

On some occasions, through and through wire stay sutures are used without any approximation of the individual fascial layers. Such wounds often are the sites for subsequent herniation. Not only does the fascia gape between the wires, but one fascial edge may be at a much deeper level than the other. Again, after wound healing is complete, there is interposition of large amounts of scar tissue between the fascial edges. As the stress on the abdominal wall continues, the scar gradually stretches and weakens while the fascial edges become farther apart.

6. *Wound Infections*

The surgeon's greatest respect and understanding probably are directed to wound infection. It is not difficult to see how bacterial infection delays healing; how enzymatic actions of cells and bacteria may destroy absorbable sutures before fascial layers become united; how tissues caught within nonabsorbable sutures, pervious to bacteria, may become acutely or chronically inflamed and

die before complete repair is achieved; and how flaps of fascia deprived of an active blood supply by dissection might become gangrenous. In fact, experiences with wound infections are so difficult to put out of mind that any postincisional hernia is likely to be credited to a low grade wound infection, even when clinical recognition of such was not made. Furthermore, when one does get around to the repair of the incisional hernia, he usually will find a defect which is resistant to simple closure. He frequently interprets this to be the result of a loss of fascial tissue from inflammatory slough. Rarely is this actually the cause of the difficulty.

7. *Delay in Tissue Growth*

A review of the common causes for infection in wounds would be incomplete without recognition of the effects which poor hemostasis and surgical trauma will exert upon the tissue. Unnecessarily extensive dissection of fascial flaps, which are thereby deprived of their normal blood supply and are reduced to a state of grafted fascia; the retention of frayed tissue; and the preservation of fragile, ischemic, old scar tissue all impose handicaps upon the speed and quality of wound healing. The character of the mechanism, as it pertains to incisional hernia, can be summarized in one statement. In experimental wounds, fibroblasts do not lay down collagen fibrils in the immediate area where leukocytic scavengers are still engaged in cleaning up debris.

The development of tensile strength will lag in wound healing where incision and repair are below a high standard of technical excellence. The race between the decline in tensile strength, based on the holding power of sutures, and the gain in tensile strength from tissue growth will be close. The clinical examination of such wounds will give little information about what is going on within. Only the surgeon who repairs each wound will be qualified to decide upon the postoperative management and privileges given the patient. Most surgeons are aware of the dangers of unwarranted strain upon fascial repairs, but in recent years it has been increasingly popular for routines of management to be set which do not take into consideration the variations in tissue repair and conditions affecting healing in the individual wounds. Partial or complete wound disruptions do occur at times; and they come with surprise, chagrin, embarrassment, and loss of explanation to the one who, as he goes about his work, closes his mind to such a possibility when he ignores the details that may account for such misfortunes.

Of course, there are delays in tissue growth associated with certain systemic diseases which produce nutritional deficiencies and metabolic disorders. The classic example is the undernourished patient with advanced cancer whose abdominal wound disrupts at the end of 2 weeks without the slightest gross evidence of tissue repair.

THE DEVELOPMENT OF INCISIONAL HERNIAS

It is not often that a fascial defect is recognized before the patient leaves the hospital. The onset of pain, paralytic ileus, mechanical intestinal obstruction

or leakage of blood-tinged fluid from a wound which should not be draining may focus attention upon the trouble; but, otherwise, the diagnosis is seldom made. If the hernia is suspected early in the postoperative course, prolonged bed rest will permit the wound to harden; and the diagnosis will again become obscure. These changes above mentioned are produced by the development and contraction of scar tissue. Even so, this scar tissue is a Trojan horse as far as future herniation is concerned.

The role of scar tissue in the development of hernias is better appreciated when the characteristics of scar tissue are fully understood. Scar begins to develop around the seventh to tenth day of wound healing, when the collagen fibrils appear in the homogenous substrate which surrounds the fibroblasts and is manufactured by them. At first, the scar tissue is soft, edematous, highly vascularized and red. Contraction of the fibrils starts by the end of the second week, progresses until the scar is completely mature and has squeezed the life out of about all of the capillaries within it. The color fades to a pale pink or white. By then the scar is hard, unyielding, and less edematous. There remains only a relatively small number of the fibroblastic cell bodies of the original granulation tissue. The collagen fibrils arrange in lines according to the stress placed upon them. The power of their contraction is great; and the force of the contraction is greatest along the longest diameter of the scar, and where the scar is thickest.

Under sudden stress, scar tissue may break. It is hard when cut with a knife or crushed in a clamp. It resists the passage of a needle but may be cut through by sutures when placed under strain. Its poor vascularity subjects it to destruction by injury, infection, tension, and pressure. Wounds created within it will heal very slowly and very poorly.

After a scar matures, some of the tension placed upon it by its own contraction, or by muscular activity, will produce some relaxation or stretching. If the tension is released by rest, contraction will recur. Scar is useful as a sealer for fascial unions but makes a poor patch for a hole in fascia.

In view of these facts, explanations for certain clinical events become available. For example, the umbilical rings in the new-born infants close entirely by the effect of scar-tissue contraction. All are potential hernias. The largest rings are the slowest to close and may present hernias quite early in life. Under truss support, many of these will improve. Under pressure and stress, they may recur. In adult years the umbilical ring may reopen from the effects of obesity, hard labor, ascites, pregnancy, etc.

Another good example of the effect of scar on herniation occurs with the McBurney incision. Since this is a muscle-splitting incision, the edges of the muscular layers automatically come together when the anesthetic wears off. The lightest of sutures prove adequate for the closure, and rarely is uncomplicated healing followed by herniation. When the McBurney wound is drained because of an appendiceal abscess, the muscle and fascial edges are kept apart for 10 days or so; and the layers fuse to each other in this abnormal relationship. A hole remains when the drains are removed. The wound closes with granu-

lation tissue and the hole eventually is plugged with a diaphragm of scar. It is through these areas of weakness that incisional hernias commonly develop in later years.

In exactly this manner does the excess scar tissue in the cicatricial plugs, which formed in the imperfectly healed fascial layers of the laparotomy incisions previously discussed, give way under stress. The plugs need not be large ones. For example, it is difficult to believe that a smaller than pencil-sized trochar and cannula, introduced through the abdominal wall for the drainage of ascitic fluid in a child with nephrosis, would create a defect that scar tissue could not support. In remissions of the disease no hernia could be found, but during periods of excessive fluid reaccumulation in some of these children, every previous tap could be identified by a hernia containing either omentum or a loop of small bowel.

Clearly, scar tissue cannot be used as a substitute for fascia. One must do everything in his power to obtain accurate fascial unions and hold to a minimum the generation of scar tissue between the layers.

THE ROLE OF THE NON-ABSORBABLE SUTURE

The value of nonabsorbable suture material in hernioplasties has been substantiated by the prolonged use of these materials in clinical practice. It seems highly probable that their advantage over the absorbable suture lasts very much longer than the first couple of weeks of wound healing.

Experimental wounds can be tested for their strength only in relation to a breaking-point. Incisional hernias seldom demand this kind of test. The process is slower. Herniation is preceded by a long period of stretching and attenuation of tissue.

If scar can be reinforced to stop its stretching, it should not rupture. The commercial substitutes for fascia are designed for this purpose. Scar growing from the surrounding living tissue will incorporate the material and bind it to the adjacent layers. Reports indicate that some hernias have recurred but none has been found to have broken through the substitute material.

The holes seemed to develop at the margins where union with the fascia had been defective. It is interesting to note that some of these substitutes were anchored with catgut. The chronicity of infections has been traced to the use of pervious, nonabsorbable material like cotton and silk, rather than the metallic mesh reinforcements. It is generally agreed and well to remember that reinforcing material is not good when placed loosely in the wound. It should be well anchored to good fascia with nonabsorbable sutures. And so, we come to the point to be emphasized. Whether the defect is repaired by imbrication of living fascia or reinforcement with commercial substitutes, nonabsorbable sutures are necessary if one expects to achieve a lasting union. If a horizontal sheet of prefabricated, nonabsorbable material placed across imbricated layers of good fascia will reinforce the scar which seals that union, nonabsorbable sutures should stop the stretching of scar which might otherwise permit the fascial layers to pull apart under stress. The trick is to keep alive the sound fascia in-

corporated in the loops of the nonabsorbable sutures. This is done by controlling those factors which throw abnormal stress on the suture line during the first few weeks of repair.

THE GROWTH OF INCISIONAL HERNIAS

When hernial contents crowd through the hernial ring into the sac, pressure is exerted on that ring to increase the size of the opening. While this plays a major role in expanding the defects in inguinal and McBurney hernias, another very great force playes a larger part in developing hernias in midline, rectus, and pararectus incisions.

Your attention is called to the powerful contractions of the external and internal oblique and transversalis muscles on the two sides. These muscles exert their forces across the midline through the fascial sheaths of the recti muscles so that they oppose each other. They form a sling in which is suspended most of the enteric tract. When that is filled with food and water, when the abdominal wall, omentum and mesentery are loaded with fat, these muscles and fascia are under a terrific strain as the individual walks about. When the common tendon, so to speak, for these muscles is incised, the wound automatically opens. It is difficult to close again without good relaxation. Any faults left in the surgical repair of the fascia are exaggerated as soon as the patient recovers from his anesthetic. The progression of the hernia is a steady and fairly rapid process in the obese patient. The ring becomes huge and often involves most of the length of the incision.

THE REPAIR OF LARGE INCISIONAL HERNIAS

At the time of repair one usually encounters real difficulties. Although the fascia may not have disintegrated, as demonstrated by the fact that one usually can dissect out fairly good fascial edges, they will not come together without a distressing and ruinous degree of tension, if at all. It was for the correction of this difficulty that investigators set out to find a reinforcement substitute for the deficient fascia. But without resorting to a prefabricated patch, in most instances something else can be done to rectify the trouble.

What happens in these patients is similar to that which takes place in muscles of the forearm when one has to postpone a primary repair of a tendon. Unopposed muscles retract; and while in that position, undergo a certain amount of fibrosis and degeneration. These abdominal muscles can be pulled out again but not with delicate strands of thread or fine pieces of wire, which behave as though they had teeth. Should one succeed in completing a difficult closure, the abnormal tension may cause the sutures to cut through the fascia during the ensuing two weeks.

While most of the measures for gaining good union in the suture line have been reviewed, a very important one has been kept in reserve for this particular place in this discussion. To assist in the closure of the most difficult cases and to insure relief from dangerous tension on those which after closure will be under greater tension than is desirable, help is available in the form of through

and through #22, steel alloy wire, stay sutures in conjunction with a standard fascial imbrication hernioplasty, using nonabsorbable sutures.

WIRE STAY SUTURES AS AN AID TO INCISIONAL HERNIOPLASTY

The fascial imbrication type of repair for incisional hernia is in common use, and wire stay sutures for special abdominal wounds have been talked about for many years. However, the combination of these two procedures is a little unusual and requires some explanation.

After identifying all layers of the abdominal wall by careful dissection and after preparing the fascia for imbrication, the omentum is spread to cover the intestines and the heavy wires are passed through the entire thickness of the abdominal wall. At intervals of about 1½ inches and at distances of approximately 1½ inches from the edges of the incision, all of the wires are placed along the entire length of the wound without attempting to close the wound. Unless one is used to working with heavy wire, he should be warned that during the interval between placement of the wires and their final twisting into position, their ends should be separately secured in heavy clamps. This is necessary to keep the wires from kinking, from tearing gloves or tissue, and from becoming tangled with other suture materials. The clamps and wire ends extending beyond the wound may be advantageously covered with towels.

The type of fascial repair is optional with the surgeon, although basically it will be in one or two fascial layers, depending upon whether the incision had been in the midline or through the rectus muscle. If the closure involves the midline, mattress sutures are placed throughout the length of the wound to eventually effect imbrication of the layers. For this, or the rectus sheath, a #00 silk or its equivalent in cotton in single strands, will work satisfactorily.

If the repair involves the two sheaths of the rectus muscle, the closure becomes a little more complicated. The posterior sheath and peritoneum usually are of rather poor quality and will not tolerate closure in large hernias without help from the heavy wires. If the wires are drawn up first, placement of interrupted sutures in the fascial layers becomes very difficult. It is reasonable, then, to place sutures without ties in both layers before the wires are tightened. The use of interrupted sutures of silk or cotton in the posterior sheath contributes to a stronger closure; but in this type of repair, the added number of loose threads extending from the wound will cause some confusion.

The advantage of starting at either end of the fascial opening of the posterior rectus sheath with a continuous suture of #0 or #1 chromic catgut and working toward the middle will become apparent as one goes along. If the closure is relatively easy, the thread can be locked at frequent intervals between wires. If the closure is more precarious, the suture can be run in a continuous manner for a distance between two adjacent wires without pulling the fascia together. The mattress sutures of silk or cotton then are placed in the anterior sheath for the same distance, but are not tied. The first wire then is snugly twisted into place as the approximation is checked with a finger inside the abdomen. Tensioe having been taken off the fascial edges by the wire, the final closure of the

fascial layers will follow. The catgut suture can be drawn up by pulling on it. If the closure is sound, it can be locked into position. If it is not sound because the loops fail to slide, exposure with smooth retractors between the wires will permit hooking of the individual catgut loops to slide the thread along. It then is locked. The threads in the anterior sheath are tied down for imbrication of the fascia and the free edge further anchored with interrupted sutures. That segment of the wound can be considered finished and one repeats the process to the next wire.

In large hernias the closure becomes more difficult as one approaches the center. In such a case, there is real wisdom in working alternately from either end toward the middle. In this manner, some relaxation is gained after a wire has been drawn up for a few minutes, making it easier to tie down the next series of sutures. As the pull on the lateral muscles of the abdomen is increased, they are found to give and the edges of the wound slowly come together. Defects in the fascia exposed after dissection often appear impossible for layer closure but are found to yield to the effects of these wires so that nothing gets caught under the loop. After the last wire is twisted into place, one can see that to have placed them any closer than 1½ inches would have endangered some part of the wound with ischemia and possibly necrosis. Also, none of the wires should be twisted tighter than is necessary to reduce the tesion and approximate the edges of the fascia.

The closure of the skin and the dressings are standard. The wires should be left in place for a minimum of 2 weeks and a maximum of 3 in the most difficult closures.

Again, it is emphasized that this type of repair is unnecessary for those hernias which occur in thin patients with good fascia, which show only small defects under little tension. In those patients where fascia has been lost by injury or disease to the extent that it is unreasonable to expect such loss to be made up by pulling out the contractions of the lateral muscles, a substitution reinforcement is perfectly acceptable. The remaining hernias involving the central vertical strip of the abdomen are greatly benefited by this method of repair.

SUGGESTIONS FOR THE MANAGEMENT OF LARGE HERNIAS

In order to facilitate a lasting repair of an incisional hernia of the abdominal wall, the following summary of suggestions is offered:

1. If the patient is obese, reduce his weight by diet until it approaches that which is normal for his height and age.

2. If time will not permit a reduction in weight or if a state of emergency exists, cleanse the colon with enemas and empty the stomach by gastric suction.

3. Do not attempt to return the contents of a very large hernia to the abdominal cavity if it has not been there for several years and the obese patient has not reduced his weight prior to the time for operation. To replace such a mass would increase the intra-abdominal tension, disturb the circulatory dynamics there, elevate the diaphragm and cause compression of the viscera of the chest, and either greatly increase the risk of fatal complications or result

in failure of the hernioplasty. If mechanical intestinal obstruction exists within the hernia sac, open it from the side where the covering is thickest, do what is necessary to release the obstruction and close the wound. At a later date, the hernioplasty can be done under more favorable and controlled conditions.

4. In the repair of hernias, do clean dissections and remove the old scar. Freshen the surfaces of the fascia which are to be placed in contact with each other.

5. Obtain complete hemostasis. Make accurate approximation of the fascial layers. Use nonabsorbable sutures and tie them securely without strangulation of tissue.

6. Consider the use of through and through wire stay sutures for the support of suture lines which are under abnormal tension and for the support of fascia which is of poor quality.

7. Employ fascial substitutes when fascia has been destroyed or a satisfactory closure is impossible, but do not employ them without some discrimination.

8. Use continuous gastric decompression until colon eliminations become spontaneous.

9. Do not feed the patient by mouth until the colon is functioning normally.

10. Do not encourage early ambulation but do encourage exercise of the legs while the patient is in bed. Patients who have wire support of the wound may sit on the side of their beds.

11. Do not allow the patient to resume strenuous exercise for at least 3 months after operation. Make the interval longer for the obese patient and maintain rigid control of his diet.

12. When candidates for hernioplasty show small hernias, start a program of repair at an early date. Do not wait for the hernias to get large and the repairs to become more difficult.

SUMMARY

Fascial substitute materials have been developed for use in the repair of severe hernias in which fascia is missing, or is of poor quality. There is some evidence that the use of these materials is growing in popularity, not so much as fascial substitutes but as reinforcements to the fascial repairs in standard hernioplasties. This is not a desirable trend, if the repairs can be successfully done without resorting to the use of such materials.

Failures in hernioplasties can be traced to basic imperfections in fascial repairs resulting from technical errors, poor wound healing, and poor management of the patient. A review of these factors has been given.

The relationship of excessive amounts of scar tissue in fascial unions to the development of incisional hernias has been emphasized. Suggestions have been given to provide greater security in fascial repairs.

Large incisional hernias develop and grow from stretching and tearing of scar tissue interposed between fascial edges. They are difficult to repair because of the contractures which develop in the lateral abdominal muscles when they

lose the effective pull of their antagonists on the opposite side of the abdomen. To overcome the effects of these contractures in severe cases, the use of #22 steel alloy, through and through, wire stay sutures is recommended to assist in the closure of the fascia and to keep the stress off the suture line during wound healing.

Additional suggestions applicable to the management of patients with large hernias have been listed.

SUPRACONDYLAR FRACTURES OF THE FEMUR TREATED BY INTERNAL FIXATION WITH IMMEDIATE KNEE MOTION

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It has long been appreciated that the prevention of chondromalacia of the patella is primary in the treatment of osseous injuries of the lower extremities. Kuntscher's development of a satisfactory technique for intramedullary fixation of fractures of the shaft of the femur represented an appreciable advance in the prevention of degenerative changes of the articular cartilage covering the posterior aspect of the patella. The shortening of hospitalization and the recovery of knee motion were relatively unimportant in comparison to maintenance of normal articular cartilage of the patella and intercondylar groove of the femur. There have been numerous efforts in recent times to provide adequate intramedullary fixation of fractures of the shaft of the tibia for the same reasons. Techniques have been outlined for intramedullary fixation of tibial shaft fractures with early mobilization of the knee joint but to date a satisfactory method has not been found which does not result in posterior angulation or at least loss of normal anterior tibial bowing with few exceptions. A method is presented for internal stabilization of supracondylar fractures of the lower end of the femur in which casting is omitted and wherein immediate knee motion is instituted.

Supracondylar fractures of the lower end of the femur, particularly those that were comminuted or in which there was spreading of the femoral condyles, or in which there was upward displacement of one femoral condyle (fig. 1), have in the past been treated by conventional methods consisting of skeletal traction through the distal femoral fragment or tibial crest, or closed manipulation followed by casting. When there was extreme comminution of the lower end of the femur with disorganization of the knee joint (fig. 2, 3), it was accepted that a painful knee with considerable restriction of knee motion would ensue. Regardless of the method of treatment employed, some degree of chondromalacia of the patella was almost inevitable. The usual surgical attack comprised arthrodesis of the knee joint.

It has been accepted that in the treatment of supracondylar fractures of the lower end of the femur, regardless of an accompanying T or Y fracture extending into the intercondylar notch, prevention of posterior angulation was difficult even though skeletal traction was inserted anterior to the axis of the rotation of the femoral condyles plus positioning of the knee in acute flexion. The problems encountered with skeletal traction, namely, posterior tilting of the fragments (particularly the distal fragment), distraction with subsequent delayed union or nonunion, or restriction of knee motion as an aftermath of traction through the tibial crest are well known. The presence of progressive chondromalacia involving the articular cartilage of the patella is indisputable in most instances treated by conventional means. The factors of compression

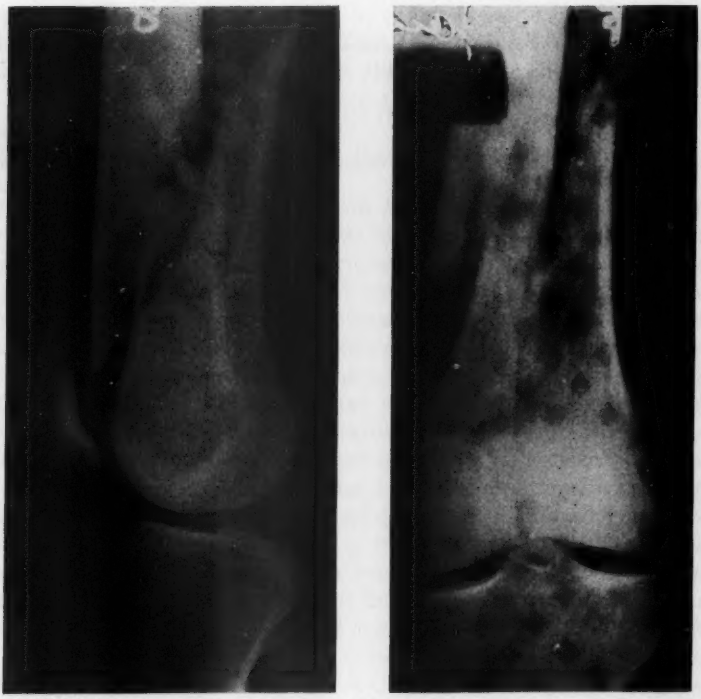

FIG. 1. H. J. Comminuted spiral fracture of the distal femoral shaft in addition to intercondylar fracture extending into the knee joint. The type of injury extremely difficult to treat by conventional means; however, internal fixation provided an excellent end result with restoration of normal anatomy.

TABLE 1

Patients	47
Nails employed	50
Male patients	29
Female patients	18
Negro patients	14
White patients	33
Youngest patient	17 years
Oldest patient	83 years
Average age	52 years

and gliding have long been known to be essential for maintenance of normal hyaline cartilage.

It is believed that fractures of this type should be regarded in the same category as intertrochanteric fractures of the femur in which internal fixation has been the standard method of treatment. Immediate internal fixation of suitable compound fractures in this series has been employed with gratifying results (fig. 4, 5a, 5b). Delayed internal fixation of selected compound fractures also has proved satisfactory (fig. 6). However, the described method of fixation has

FIG. 2. S. G. Comminuted supracondylar fracture with excellent reposition of fragments despite short distal femoral fragment.

TABLE 2

Closed fractures	40
Compound fractures	10
Shortest interval between injury and surgery	1 day
Longest interval between injury and surgery	185 days
Average	17.8 days
Average hospitalization	37 days
Formal physical therapy	4 patients
Average interval between surgery and partial weight bearing	119 days

been found to be especially helpful in cases of established nonunion in which it is desired that there be no additional immobilization of the knee joint.

The Blount nail appears to be more satisfactory than any other type of decribed angled nail inasmuch as this type of internal fixation lends itself readily

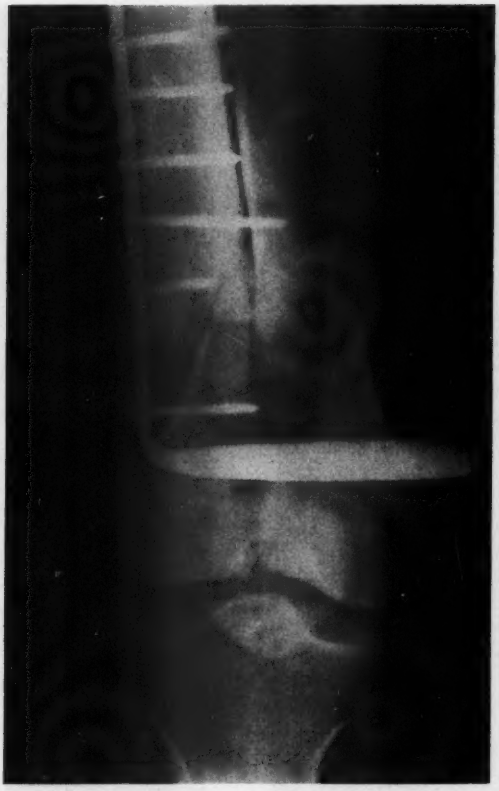

FIG. 3. R. D. Complete disorganization of the lower end of the femur that defies anatomic restoration. Internal fixation with acceptable position despite lateral shift of the shaft of the femur. Justifiable criticism is that the nail is too long. However, the patient obtained a range of active knee motion of 90° to 180°, although he required ½ inch elevation to the heel to compensate for leg discrepancy.

to adaptation by bending to conform to the condyle of the femur as well as obtaining an acute angle for adequate stabilization of a short distal femoral fragment (fig. 7). This is an important technical point inasmuch as it has been necessary to bend the nail to a right angle to control an extremely short lower fragment (fig. 8, 9). If the plate cannot be closely approximated to the contour of the femoral condyle fixation of the fragments in valgus or varus may ensue. Clinical results have even been satisfactory when the tip of the nail entered the the knee joint provided the weight bearing portion of the femoral condyle was not violated (fig. 10). Experience has shown that there exists a tendency to fix the fragments in valgus in an appreciable number of instances and for that reason several large pillows or sandbags are inserted between the knees when positioning the patient on the operating table in order to provide a fulcrum for adduction of the distal fragment.

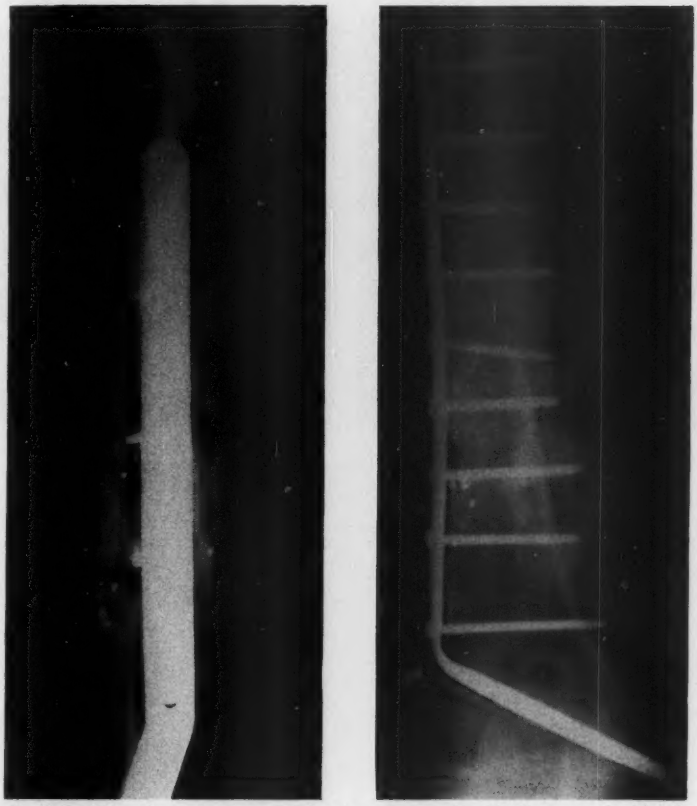

FIG. 4. V. R. Comminuted compound fracture the result of bullet wound which has been anatomically restored by internal fixation. The Blount nail was inserted at the time of the original debridement.

Three patients fell, with resultant bending of the plate and angulation of the fragments of the femur (fig. 11, 12). In all instances satisfactory reduction was obtained following manipulation under intravenous anesthesia. It was gratifying to observe that firm internal fixation of both proximal and distal fragments of the femur was maintained despite forceful manipulation under general anesthesia. It was our original belief that it was most essential that the cortex of the condyle on the side opposite to the side of insertion of the Blount nail be penetrated by the tip of the nail in order to secure adequate fixation (fig. 13), particularly when dealing with T or Y fractures (fig. 14), or when spreading or rotation of the condyles was anticipated. Only by accident it was learned that fixation could be maintained in all cases, even those with Y or T fractures, in spite of the fact that the tip of the nail stopped short of actual penetration of the opposite cortex.

Even in those cases in which the nail lacked as much as ½ inch of reaching

FIG. 5a FIG. 5b

FIG. 5a. S. D. Comminuted compound fracture of distal femoral shaft treated by debridement and skeletal traction through the tibial crest. Internal fixation believed to be unwise in view of contamination of wound. Satisfactory early union 4½ months after injury.

FIG. 5b. S. D. Internal stabilization of the compound fracture of 5a, following refracture 6 months after the original injury. Excellent healing by internal fixation in fracture originally compounded with no reactivation of infection following insertion of nail.

TABLE 3

End results

Excellent and superior—full range of knee motion with no chondromalacia of the patella	23
Good—active knee motion from 90° to 170° with minimal chondromalacia of the patella	11
Fair—active knee motion from 120° to 160° with moderate chondromalacia of the patella	2
Poor	10
(a) Internal fixation pulled loose in decalcified bone. Patients had been bedridden for many months prior to injury	3
(b) Rheumatoid arthritics with appreciable restriction of knee motion as well as decalcification prior to Blount nailing	4
(c) Internal fixation in patient with generalized carcinomatosis	1
(d) Ancient tear of patellar tendon which prevented complete extension of the knee joint	1
(e) Death 8 days after surgery	1
Inadequate follow-up	4

TABLE 4

Errors in fixation in position of fragments

Included are cases that had only a few degrees of variation from normal.

Fixation in valgus	12
Fixation in varus	4
Fixation with posterior bowing	7
Fixation with lateral displacement of the femoral shaft	6

FIG. 6. A. G. Delayed internal fixation of markedly comminuted compound supracondylar fracture with anatomic alignment of fragments. Blount nail inserted 19 days after injury.

TABLE 5

Penetration of opposite cortex by nail

A. Nail did not penetrate cortex of opposite condyle:	
Excellent	15
Good	8
B. Nail penetrated cortex of opposite condyle:	
Excellent	8
Good	3
Fair	2

TABLE 6

Additional procedures

Blount nails removed after union was obtained	10
Skin grafting procedure	1
Long leg cast applied immediately postoperative (carcinomatosis)	1
Bone graft—secondary to nonunion due to a fall following original surgery	1
Bone graft for nonunion	1
Application of skeletal traction because of inadequate internal fixation	2
Neufeld nailing of intertrochanteric fracture on same side	1

the opposite cortex excellent stabilization was maintained. Consequently it is now our routine to select a Blount nail of such length that the nail lacks ½ inch of reaching the opposite cortex. In no instance has there been any rotation or diastasis of the condyles in patients in which the nail failed to engage the opposite cortex.

TECHNIQUE

The Blount nail has been inserted through a lateral approach in the majority of cases but there were a few instances in which more satisfactory fixa-

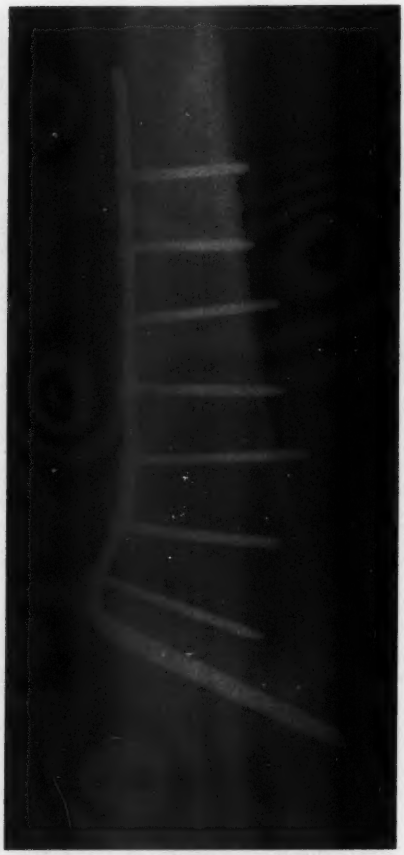

FIG. 7. A. B. Satisfactory length of nail with molding of the plate by bending irons to conform to the flare of the lateral femoral condyle. Note curve of plate and position of nail to provide adequate fixation of the supracondylar femoral fragment.

tion could be obtained by insertion through a medial incision (fig. 10). Medial insertion is advisable when the injury leaves a distal fragment with a short lateral cortex. Careful positioning of the pneumatic tourniquet at the highest level of the thigh is compatible with adequate exposure. With the patient lying in the lateral position with the injured thigh uppermost, a vertical lateral skin incision of 8 to 10 inches has been found to be adequate. The skin incision should extend to the level of the knee joint for suitable exposure of the condyle but it is never necessary to open the knee joint. Following division of the fascia lata, the vastus lateralis muscle fibers are split by blunt dissection. A gently curved V shaped cut then is made into the lateral cortex of the condyle or femoral shaft by means of an osteotome. An angled nail and plate of suitable length

FIG. 8. J. H. Excellent reposition of extremely comminuted fragments by internal fixation. The nail represents correct length and penetration. The necessity of bending the nail to a right angle to provide adequate fixation of the distal femoral fragment is demonstrated.

is then inserted, the plate temporarily held in apposition to the shaft by a Lowman clamp. The importance of having a clamp available to maintain the plate in proper relationship to the shaft of the femur can only be appreciated by those who have performed this type of surgery. Anteroposterior and lateral portable roentgenograms then are taken. If the operating room roentgenograms reveal satisfactory position of the Blount nail the plate is fastened to the shaft of the femur by adequate screw fixation. It is essential that the nail be of such length that it stops short of penetration of the opposite femoral cortex by ½ inch inasmuch as it is impossible to prevent involvement of the collateral ligament of the knee joint by the tip of the nail even though it barely penetrates the cortex of the opposite condyle. The involved collateral ligament thus becomes

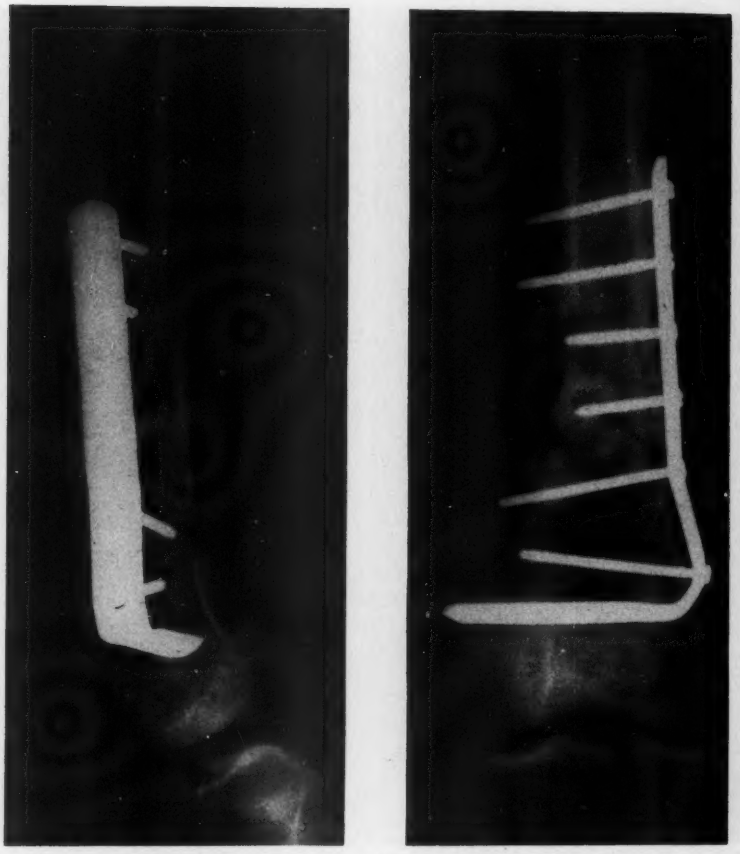

FIG. 9. A. D. Additional example of necessity of bending nail to an acute angle to provide firm fixation of distal femoral fragment.

bound down by adhesions with appreciable restriction of knee motion. In those instances in which a medial approach to the lower end of the femur is deemed advisable, it has been found to be most expedient if the patient is anesthetized in the supine position with the opposite hip elevated on a sandbag followed by external rotation of the involved leg plus flexion of the knee joint to almost a right angle. It is of paramount importance that true lateral portable roentgenograms are obtained at the time of surgery. Often the tip of the nail will appear to have entered the knee joint when the portable lateral roentgenogram is reviewed, but usually this is not srue (fig. 14). Before release of the pneumatic tourniquet a compression dressing, consisting of several rolls of sheet-wadding followed by application of two 6 inch elastic dressings, then is applied and this

FIG. 10. M. W. Comminuted supracondylar fracture with insertion of Blount nail by medial approach. An example of penetration of the nonweight bearing portion of the knee joint with little or no clinical significance.

compression dressing is left undisturbed for 48 hours. When the compression dressing is removed the patient is placed upon flexion exercises over the edge of the bed carried out on an hourly basis. Quadriceps setting exercises are initiated on the day following surgery.

With few exceptions the initial primary treatment consisted of skeletal traction by means of a Kirschner wire inserted through the tibial crest. The majority of patients were operated upon on an elective basis.

It has been our experience that internal fixation has been entirely satisfactory in all types of fractures of the lower end of the femur, even those which were so comminuted as to create doubt that adequate reduction could be maintained.

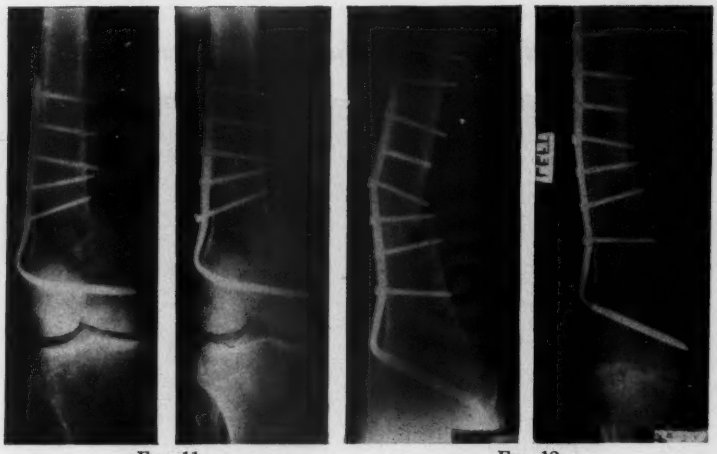

FIG. 11 FIG. 12

FIG. 11. H. C. Lateral angulation of femoral fragments following fall on a wet floor. Correction of the varus deformity by manipulation under anesthesia.

FIG. 12. L. S. Appreciable lateral angulation of the plate resulting from a fall out of bed. Acceptable but not anatomic realignment of the fragments following manipulation under anesthesia.

FIG. 13. H. J. Comminuted T fracture which has healed in excellent manner. Nailing was carried out without attempt to correct the few millimeters of diastasis of the femoral condyles. The nail lacked 4 to 5 millimeters of engaging the opposite femoral cortex. Example of no additional spreading of the femoral condyles when compared with original roentgenograms.

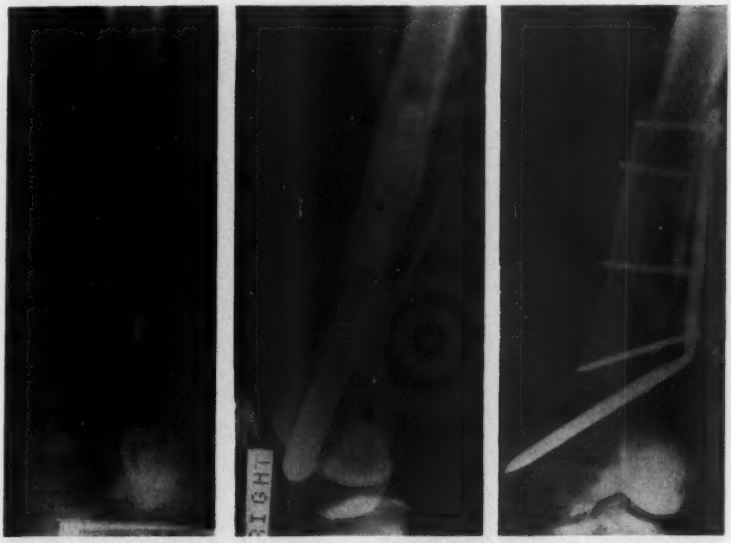

FIG. 14. R. McG. Satisfactory fixation of comminuted T fracture. Anteroposterior projection refutes the impression given by the lateral view of violation of the knee joint by the nail.

TABLE 7

Complications

Surgical infections	3
(a) drainage for 17 days from time of surgery	1
(b) drainage for 20 days from time of surgery	1
(c) redness and swelling first appearing 21 months after surgery; treated by incision and drainage by family physician. Slight drainage still present when last seen 25 months postoperative	1
Thrombophlebitis	2
Death—8 days postoperative	1
Pulmonary infarct	1
Postoperative pneumonia	1
Cystitis	1
Sacral decubitus	1
Patients falling and bending angled nail, requiring manipulation under general anesthesia	3
Lateral femoral condyles pinned with upward displacement	2
Nonunion requiring bone graft	2

Fixation of Y and T fractures has revealed that there was no additional spreading of the condyles of the femur over that degree of diastasis that was deemed acceptable at the time of surgery. It is believed that the collateral ligaments of the knee joint exert mild lateral compression in Y and T fractures inasmuch as the Blount nail fixation was thought to be so precarious in certain comminuted

FIG. 15. E. S. Loss of internal stabilization due to inadequate fixation of the proximal fragment by a plate that was too short.

fractures that it was difficult to understand how the nail alone could prevent additional spreading of the condyles (fig. 13).

Without exception the unsatisfactory results have been due to errors in the selection of patients or to mistakes in surgical technique. None of the poor end results can be attributed to the described treatment (fig. 15, 16). The majority of patients were operated upon in a teaching, charitable city hospital, by the surgical residents. On several occasions mature judgment would have dictated continued skeletal traction or treatment other than open reduction with internal fixation. Patients who have been bedfast or arthritics on a nonweight bearing status are unsuitable for internal stabilization by nailing. The cortex of the lower end of the femur is appreciably thinner than that of the shaft of the

FIG. 16. J. W. Failure of internal fixation despite employment of plate on opposite side. Patient was a bedridden arthritic who had not walked for several years. Represents excellent example of misuse of internal fixation.

femur so when disuse decalcification is added, the failure of the nail and screws to maintain fixation can be readily appreciated. It is impossible to maintain a Blount plate in satisfactory position in soft, decalcified bone even when an additional plate is inserted on the opposite side of the lower end of the femur.

The method described also has been satisfactory when only one condyle was fractured (fig. 17), as well as those instances in which there was appreciable length to the distal femoral fragment (fig. 18, 19). An acceptable clinical end result was obtained in two instances despite fixation of one femoral condyle in valgus position with depression of the weight bearing surface of the medial condyle as compared with the lateral femoral condyle (fig. 20). Delayed open

FIG. 17. T. C. Less common injury with satisfactory internal stabilization of the fracture of the medial condyle. The correct length of nail is illustrated.

reduction usually mitigates against accurate and satisfactory reposition of the femoral fragments (fig. 21).

ANALYSIS OF CASES

Analysis revealed that the described method is applicable to patients regardless of age. Internal fixation of the fragments in selected compound fractures can be carried out at the time of original debridement immediately after the injury. It is to be emphasized that the extremely satisfactory results obtained in the majority of patients have been despite the fact that only 4 patients received formal physical therapy. Approximately one-fifth of the Blount nails were removed for various reasons after providing the necessary internal fixation. Skeletal traction following surgery was required on two patients due to inadequate internal fixation of the proximal fragment (fig. 15).

Recovery of 3 patients was complicated by surgical infection, all of which

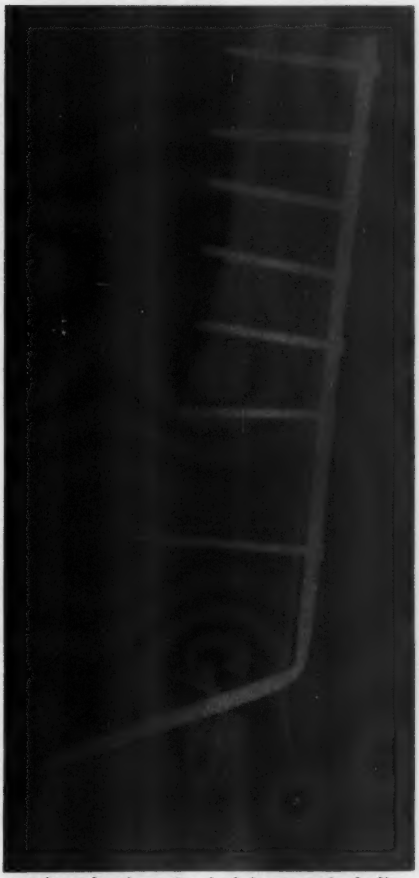

FIG. 18. W. N. Anatomic reduction of spiral fracture including a butterfly fragment. Example of excellent fixation of segmental and long distal fragment.

occurred in closed fractures. However, none resulted in any appreciable or persistent infection.

It is our belief that our most serious error in surgical judgment was the selection of patients for internal fixation whose bones were so decalcified that firm fixation of the Blount nail to the shaft of the femur could not be maintained. Statistics reveal that three times as many patients had fixation in some degree of valgus as compared to those fixed in varus. It is significant that in the entire series there was no instance of fixation in appreciable anterior bowing or medial displacement of the femoral shaft. Six patients had internal stabilization with some lateral displacement of the shaft but such a shift did not appear to have any appreciable significance upon the ultimate clinical result.

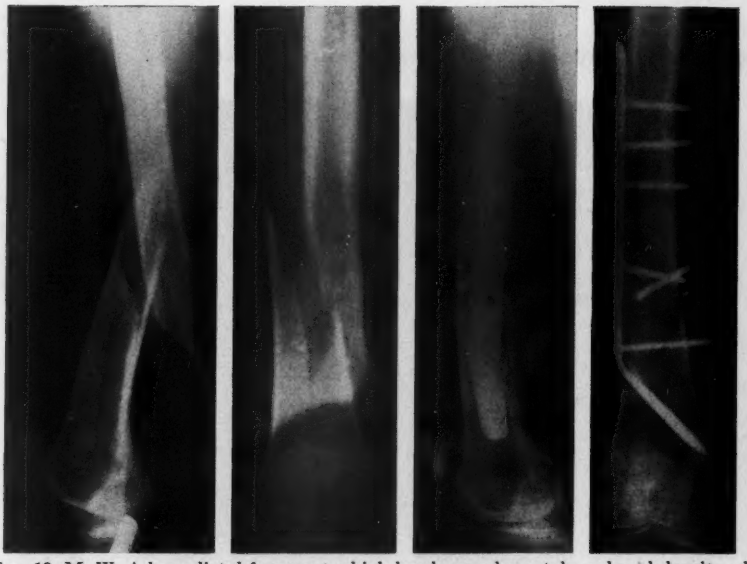

FIG. 19. M. W. A long distal fragment which has been adequately reduced despite additional comminution of the distal fragment at the time of surgery.

FIG. 20. J. H. Very satisfactory clinical result despite fixation of medial femoral condyle in depressed and valgus position.

FIG. 21. R. K. Exuberant callus accompanied by appreciable restriction of knee motion. Delayed open reduction and internal fixation approximately 4 weeks after injury.

The level of the fracture as measured by the distance above the knee joint did not appear to have any significant relationship to the ultimate end results. There did not appear to be any relationship between the amount of bony callus at the level of the fracture and range of knee motion obtained.

Physical therapy consisted of flexion exercises over the edge of the bed plus quadriceps resistance exercises except in 4 patients who received additional formal physical therapy. Quadriceps setting was initiated 24 hours after surgery and knee bending over the side of the bed 24 hours later.

The angle of the nail portion to the plate portion appeared to have no significance in capacity to stabilize and firmly maintain the distal fragment.

It probably is of no significance that in the three instances of bowing of the plate and fragments following a second injury that the angulation was lateral, resulting in varus deformity. In all instances satisfactory correction was obtained by manipulation under general anesthesia but it would appear to be significant that neither the nail nor plate pulled loose following forcible manipulation.

There did not appear to be any precise and absolute correlation between

the clinical impression of union and radiologic findings. The ultimate decision to allow partial weight bearing depended, as always, upon surgical judgment.

Private patients were hospitalized for a shorter period of time and obtained a higher percentage of satisfactory end results when compared to service cases.

SUMMARY

Internal fixation of supracondylar fractures of the femur has been proved to be a most satisfactory method of treatment.

The described method of treatment has reduced the incidence of chondromalacia of the patella as well as resulting in shortening the periodfo hospitalization.

Fixation of the cortex of the opposite femoral condyle has been shown to be nonessential. Internal fixation may be employed at the time of the original surgery in certain selected compound fractures.

The desirability of employing a method of internal fixation in which the angle of the nail can be altered is described.

The unimportance of formal physical therapy in obtaining satisfactory results should be noted.

Poor results were due to errors in surgical judgment rather than to failure of the method of treatment.

EDITORIAL

THE FUTURE OF ANTIBIOTIC TREATMENT IN SURGERY

Any prediction of the future is difficult, and that of antibiotic therapy is particularly so. The therapeutic miracles provided by penicillin have been followed by significant extension of the scope of surgical treatment made possible, to a large degree, by the control of previously complicating infections. The rapid discoveries of streptomycin, the various tetracyclines, bacitracin, chloramphenicol, erythromycin, and other antibiotics have increased the number of powerful agents available for selection and the possibilities as to their use.

In their zeal to give patients the most complete antibacterial coverage, surgeons have commonly used combinations of two, three, or more antibiotics simultaneously. At the same time, they developed a curious and unfaltering faith in the prophylactic value of penicillin. Physicians, also, extended antibiotic therapy to many patients with undiagnosed fevers, infections not susceptible to the agents, minor or trivial wounds, and clean or aseptic operations.

As a result of these developments, the incidence of certain complications of antibiotic therapy has been accentuated, resulting in limiting and deleterious effects on the response to treatment. They will almost certainly have a profound influence on the future of antibiotic therapy.

To get a glimpse of the status of antibiotic treatment in the next 10 years, let us examine the effects which have limited the application and effectiveness of antibiotic treatment to varying degrees in the past 10 years. These may be grouped into four broad categories:

(1). Changes in the susceptibility of bacteria to the antibacterial action of the antibiotic agents;

(2). Complications occurring in patients as a direct or indirect result of the use of chemotherapeutic agents;

(3). The economic impact of the cost of chemotherapy; and

(4). The influence of antibiotic therapy on clinical surgeons.

The widespread use of the many antibiotic agents has resulted in an alarming development of resistant groups of bacteria. This *acquired resistance* has had a serious effect on the population as a whole, particularly in hospital practice. An important example of this has been the progressive resistance of the pathogenic staphylococci, first to penicillin and more recently to other chemotherapeutic agents. When penicillin was first introduced for clinical trial in 1943, it was effective against 93–95 per cent of the virulent staphylococci. During the ensuing 12 years, this percentage has gradually decreased year by year, until it is generally agreed now that the majority of strains are resistant. Many are also resistant to the tetracyclines, as well as streptomycin. All but a few, however, are still sensitive to erythromycin, chloramphenicol and bacitracin. The persistence of a high percentage of staphylococcal susceptibility to chloramphenicol has been of particular interest.

Fortunately, some of the bacteria, such as the beta hemolytic streptococci

and pneumococci, have not developed acquired resistance, while in others, particularly the gram-negative bacilli of the colon group, this has been and will continue to be an important factor. Presumably, the increase in antibiotic resistance results from the suppression of sensitive bacteria and selective proliferation of resistant variants arising by mutation during therapy.

Many of the patients in the tuberculosis sanitoria today harbor streptomycin-resistant tubercle bacilli. The future will tell whether or not the same phonemenon will be an important problem with isonicotinic acid hydrazide. In the treatment of tuberculosis, however, it has been found that the development of resistance can be delayed or prevented by the concomitant use of two or three effective agents.

There can be no doubt but that the problem of acquired resistance is a serious one and that it will become more serious during the coming years. Perhaps experimental work will demonstrate methods of reversing the resistant state to a susceptible one. A ray of hope in this direction has been the demonstration in our laboratory that the incidence of resistant strains of hemolytic *Staph. aureus*, cultured from surgical infections in hospitalized patients, has fluctuated between 18 and 82 per cent over 3 month periods during the past 5 years. If the significance of this observation could be determined by experimental work, some lead for the prevention of acquired resistance might be obtained. In the meantime, the reservation of erythromycin for the treatment of established infections caused by resistant staphylococci should be considered.

Complications of antibiotic therapy, which have limited its usefulness in surgery and will undoubtedly continue to do so, include sensitization of an increasing proportion of the population to the different agents, the development of toxic reactions, the occurrence of secondary or superimposed infections, and the masking of infectious lesions.

In the case of penicillin, the incidence of acquired sensitivity by patients varies between 2 and 16 per cent, and our hospital experience indicates the latter figure to be more accurate. This probably will increase during the next 10 years. It is unfortunate that sensitized individuals will be denied the further benefits of this agent or be subjected to serious risks if it is given. Increasing instances of anaphylactic shock and death immediately following the injection of penicillin are being reported from many areas of the country.

The toxicity of the various antibiotics differs considerably, but most, if not all, of them are capable of producing one or more types of reaction. Those caused by over-dosage can be readily prevented or controlled. Those secondary to an idiosyncrasy are fortunately rare but very serious. Idiosyncrasy to chloramphenicol, with depression of the bone marrow and leukopenia, agranulocytosis, or aplastic anemia, received considerable publicity in 1951 and 1952. Approximately 75 proved cases of blood dyscrasia were collected from the literature and the anticipated incidence of this complication for the present and future has been fixed at 1 in 40,000. The use of chloramphenicol probably will be extended as the fear of this complication is dissipated.

The development of superimposed infections complicating treatment with

broad-spectrum antibiotic agents is worthy of special consideration. Secondary infections may develop within a wound or elsewhere in the body which may be very serious. Contributing factors include infection by micro-organisms other than the primary etiologic agent which are resistant to the antibiotic agent in use. Instances of spontaneous septicemia produced by strains of *B. proteus* and staphylococci have been observed by us as examples of superinfections. Another more spectacular example is pseudomembranous enterocolitis which has been reported during therapy with one of the tetracyclines. Unless recognized promptly and treated actively, this complication often is quickly fatal. The incidence and mortality rate of such infections should be lessened in the next 10 years through education of the practicing clinicians.

Monilial infections of the mouth, rectum, vagina, or respiratory tract also may develop secondary to broad-spectrum therapy. It should be emphasized, however, that the laboratory demonstration of monilia in discharges from lesions does not necessarily indicate their etiologic association with clinical infection.

While the question as to whether or not fungal infections are increasing as a result of antibiotic therapy cannot be answered definitely now, there is little doubt as to the occurrence of such infections during antibiotic treatment and the difficulty of their management when established.

The masking or the attenuation of infections developing in patients under antibiotic therapy may make the surgeon unaware of their existence because of the absence of the usual local signs of inflammation. Nevertheless, they may be dissecting, extensive, or even lethal. In our report of 93 fatal cases of septic shock seen at the Cincinnati General Hospital during the past 5 years, it was noted that many of the patients had severe infections associated with uncontrolled vasomotor collapse which developed during antibiotic treatment. This raises the question as to how much the incidence of severe infections in surgery actually has been decreased during the past 10 years. There is evidence that this decrease is not as great as generally supposed. Unless surgeons become more adept at diagnosing infections obscured or masked by chemotherapy, the beneficial effects of this form of therapy will continue to be limited.

To minimize the occurrence of these hypersensitive, toxic, and infectious complications in the future, automatic stop-orders at 48-72 hours should be adopted for the broad-spectrum antibiotics. This policy would force the clinician to review his antibacterial therapy regularly and would eliminate prolonged periods of treatment or excessive dosage with these agents, the two factors which contribute significantly to the development of untoward reactions.

The *economic effects* of antibiotic treatment on patients, hospital budgets, insurance programs, and society in general are of particular interest. The magnitude of their impact can be appreciated if one considers that over one-half of all prescriptions written today are for antibiotics. There is little doubt but that present practices are wasteful and that they cause appreciable expense to all concerned. At the Cincinnati General Hospital, a University teaching institution, the expenditure for antibiotics has steadily increased from $24,-

467.64 in 1950 to $65,310.00 in 1955. At the Children's Hospital in Cincinnati, the average cost on an over-all patient-day is $6.00 which represents a 50 per cent increase over the $4.00 cost per day for antibiotic treatment 2 years ago.

Statistics for Blue Cross-participating hospitals in southwestern Ohio, as furnished us by the Hospital Care Corporation, show an increasing cost per day of dressings and drugs, including antibiotics, from $1.40 in 1947 to $2.89 in 1955. An additional increment probably is obscured by the fact that the figures before 1953 pertain to both in-patients and out-patients, whereas those after 1953 pertain only to in-patients. Unfortunately, a breakdown of the additional cost to the Blue Cross Plan of antibiotic therapy alone is unavailable.

Since the wholesale prices of antibiotics have not advanced materially in recent years, the increase in the patient's cost is the result of the trend toward larger doses, more extensive use of the broad-spectrum agents, and increased administration of the more expensive parenteral forms. In some cases the cost of antibiotic therapy has amounted to $27.60 per day. Regardless of the cost, it is important to keep in mind the great beneficial effects provided patients by antibiotic therapy and the significant decrease in the average period of hospital stay.

The *influence of antibiotic therapy on clinical surgeons* should not be underrated. The many miracles produced by the antibacterial agents have resulted in an exaggerated impression of their clinical possibilities and a blind faith in their effectiveness, neither of which is based upon fact. Other important therapeutic principles, technical details, or other factors are often overlooked on the assumption that antibiotic therapy is the prime treatment for the prevention or control of an infection.

A motivating influence in the surgeon's excessive use of antibiotics unquestionably has been the request or demand of the patient or his family. Too often, these agents have been given to bolster the confidence of the patient, his relatives, or his family physician. The active and persistent education of the public, as well as the medical profession, which is now underway will eliminate this source of pressure and permit the surgeon to elect antibiotic treatment on a more rational basis. Experience has emphasized to him that antibiotics are most effective when used in conjunction with careful and adequate surgery, and that they cannot be substituted for careful diagnosis or thoughtful surgical management. The growing recognition of this fact will undoubtedly have a beneficial effect on antibiotic treatment in the next 10 years.

Another trend has been the growing tendency of some physicians to rely too strongly upon the results of bacterial cultures. In this manner, false diagnosis and ineffective treatment may result from the culture and identification of bacteria other than the true etiologic agents. This trend must be altered so that antibiotic agents are correctly chosen on the basis of the correct diagnosis and their effect on the true etiologic agents of that disease.

The prophylactic value of antibacterial agents for the prevention or suppres-

sion of infection developing in contaminated wounds is noteworthy. Their chief value lies in the attenuation, limitation, or control of infection in wounds by residual bacteria after debridement. However, infections complicating wounds of violence still remain a very important problem in both civilian and military practice, antibiotic therapy notwithstanding. Another potentially important prophylactic asset is the localization or retardation of infection developing within wounds of patients in whom surgical treatment is necessarily delayed or impossible. This would obtain particularly in the event of an atomic attack, when our main reliance against the development of severe overwhelming or invasive infections would depend necessarily upon the early administration of the antibiotic agents.

There are still large gaps in our therapeutic armamentarium, particularly involving the fungi, viruses, and certain gram-negative bacilli such as *B. proteus* and *B. pyocyaneus*. There is, of course, the hope that antibiotics effective in the treatment of tumors also may be found. From the favorable recent reports of experimentally effective drugs in these areas and the tremendous amount of time and money that is being applied in this direction, it seems highly probable that answers to many of these problems may be found in the near future. Most of the progress in the development of new drugs has come from the broad screening programs carried on by the commercial drug companies. In spite of obvious disadvantages of this method, it promises to continue to be the most productive.

Another potential extention of antibacterial treatment is possible through the combined use of steroids and antibiotics under certain conditions. To date, this type has been explored principally in overwhelming infections associated with severe collapse and shock. This form of treatment is still questionable in the minds of many physicians because of the reduction of the patient's resistance to bacterial invasion and dissemination associated with the administration of cortisone and ACTH.

It would appear that the answer to the question, "Will the present benefits of antibiotic treatment continue for the next 10 years?", depends largely upon our ability to profit from our past experiences and to correct those practices which are limiting or eliminating the effectiveness of antibiotic agents. Active education of the physicians and general public in the dangers of indiscriminate use of antibiotics and more thoughtful consideration of the indications for these agents will do much to preserve their effectiveness for future patients and surgeons.

"There is no good without ill in the world, but everything is mixed in due proportion." "The evil that men do lives after them; the good is oft interred with their bones."

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BOOK REVIEWS

The editors of THE AMERICAN SURGEON *will at all times welcome new books in the field of surgery and will acknowledge their receipt in these pages. The editors do not, however, agree to review all books that have been submitted without solicitation.*

Fractures of the Facial Skeleton. By N. L. ROWE, FDSRCS (Eng.), LRCP (London) MRCS (Eng.), Consultant in Oral Surgery, Plastic and Maxillofacial Surgery Unit, Rooksdown House, Basingstoke and H. C. KILLEY, FDSRCS (Eng.), LRCP (London), MRCS (Eng.), Consultant in Oral Surgery, Plastic and Maxillofacial Surgery Unit, Rooksdown House, Basingstoke. Baltimore, The Williams & Wilkins Company, pp. 923. Price $22.00.

This new book deals exhaustively with fractures of the facial bones and associated injuries. Separate chapters on injuries to the soft tissues, the brain, anesthesia in these problems, radiography and other matters pertaining to this field are included by other authorities. As this is an English publication, the methods of reduction and fixation described are often at variance with those in common use in this country. The information presented is sound and the procedures are adequately described and illustrated. An interesting chapter of the book is the historical background of the treatment of maxillofacial injuries. This volume will prove to be a useful and interesting atlas for those having to treat these frequently difficult problems.

FRANK F. KANTHAK, M.D., D.D.S.

BOOKS RECEIVED

Books received are acknowledged in this section, and such acknowledgment must be regarded as a sufficient return for the courtesy of the sender. Selections will be made for review in the interests of our readers and as space permits.

Scalpel: Men Who Made Surgery. By AGATHA YOUNG, New York, Random House, 1956. $5.00.

Cardiovascular Innervation. By G. A. G. MITCHELL, O.B.E., T.D., M.B., Ch.M., D.Sc., Professor of Anatomy and Director of the Anatomical Laboratories in the University of Manchester, Hon. Alumnus, University of Louvain, foreword by Sir Geoffrey Jefferson, C.B.E., M.S., M.Ch., M.Sc., Ll.D., F.R.C.P., F.R.C.S., F.R.C.S.I., F.R.F.P.S., F.A.C.S., F.R.S., Emeritus Professor of Neurological Surgery in the University of Manchester. Baltimore, The Williams & Wilkins Company, 1956. $11.00.

The Cellular Basis of Wound Repair. By MARTIN ALLGOWER, M.D., Privatdocent, Department of Surgery, University of Basle, Switzerland, formerly, Research Associate, Department of Plastic and Maxillofacial Surgery and Tissue Culture Laboratory, University of Texas, Medical Branch, Galveston. Springfield, Illinois, Charles C Thomas, 1956. $6.50.